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BIOLOGICAL-ECOLOGICAL ASPECTS OF BETATAKIN CANYON NAVAJO NATIONAL MONUMENT ARIZONA

by

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FOREWORD

This study was conducted to define the biological and ecological potentials of Betatakin Canyon in Navajo National Monument for the purpose of providing in readily available form pertinent information useful in the interpretative program of the monument. The proposals for interpretation of these features were developed in cooperation with Interpretive Planner David J. Jones, Monument Superintendent Arthur White and Chief Ranger Buddy Martin, to provide close coordination between the results of this study and the program of the National Park Service.

The data incorporated in this report have come from many sources. A lifelong acquaintance with the rough canyonland country of the American southwest, two summers of exploration in the Navajo Country (1937 and 1938), and a field trip to Betatakin Canyon, September 17 to 21, 1962 furnished the background.

I appreciate the assistance rendered by the Museum of Northern Arizona, especially W. B. McDougall and Milton Wetherill, and that from Dr. Stephen D. Durrant, University of Utah.

Angus M. Woodbury

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INTRODUCTION

Betatakin Canyon in the Navajo National Monument, Arizona, is cutting a thousand feet in depth headward into a highland plateau covered with a pinyon-juniper pigmy conifer forest. This canyon has a profile of cliffs cut through Navajo, Kayenta, and Wingate sandstones which represent three out of a series of five great sandstone cliff-making sedimentary formations laid down in this region during earlier geological times, all of Jurassic age (Baker, et al., 1936:45-49). According to Stokes and Holmes (1954:34-41), all five originally covered this region as shown in Figs. 1 to 5. It is presumed that the upper two, Mt. Carmel and Entrada sandstones have been mostly if not entirely removed by erosion at Betatakin.

The great system of Segi canyons drains a series of canyon heads similar to that of Betatakin, providing great scenic features, Fig. 6. Ecologically the primary effect of such a canyon head is to cut the aquafers carrying sparse supplies of water percolating through the sandstone and to shut out of the canyon depths much of the daily sunshine. This reduces potential evaporation and enhances higher humidity in the canyon depths. In effect, it is a miniature Zion Canyon draining in opposite direction. It has a "canyon effect" as described for Zion by Woodbury (1933).

The aquafers cut by the canyon range from percolating water emerging as springs and through minor seepage areas that moisten the cliff faces to porous spaces in the sandstone that allow water to evaporate from its surface without visible wetting. Water emerging from such aquafers is the primary agent in the development of alcoves and caves although the structure of the sand in the dunes from which the sandstone was formed has an important bearing upon the path of the aquafers, the point of emergence at the surface, and the erosion resistance of the rock. The development of alcoves into caves is accelerated by the presence of water. Size of caves is often correlated in a general way with the amount of water involved.

The "canyon effect" is produced mainly by the high canyon walls shutting out the daily sunlight. The deeper and narrower the canyon, the more the sunshine is excluded and less sunshine provides less energy available for evaporation of water. In effect, the climate is inverted from that of a mountain so that there is a gradation downward toward cooler and more humid conditions in the bottom. This inverted climate is correlated with flora and fauna to match. However, canyons are so irregular in aspect that there are many anomalies in distribution of the plants and animals.

Normally, a high mountain such as Navajo, Fig. 7, has an arrangement of vegetation belted like that shown in Fig. 8 which depicts a generalized arrangement on a mountain in Utah. The belts usually turn upward on south-facing slopes and dip downward on the north side. This drawing is approximately typical of Navajo Mountain visible from Navajo National Monument except that its base is in the pinyon-juniper pigmy forest belt and its summit in the large conifers does not reach the tundra zone.

Although a deep and narrow canyon has a general resemblance to an inverted mountain, actually there are detailed differences in the natural forces sculpturing the physiographic features. Some of these are shown in the canyon sketch in Fig. 9. The direction a canyon runs helps in determining the aspect

Maps shown in Figs. 1 to 5 illustrate the former distribution and thickness of the five principal cliff-forming sandstones of southeastern Utah and adjacent states around Four Corners, according to U S G S Prof. Paper 183: 45-49. Each succeeding map lies above the preceding maps. See Stokes and Holmes (1954:34-41).

WINGATE SANDSTONE

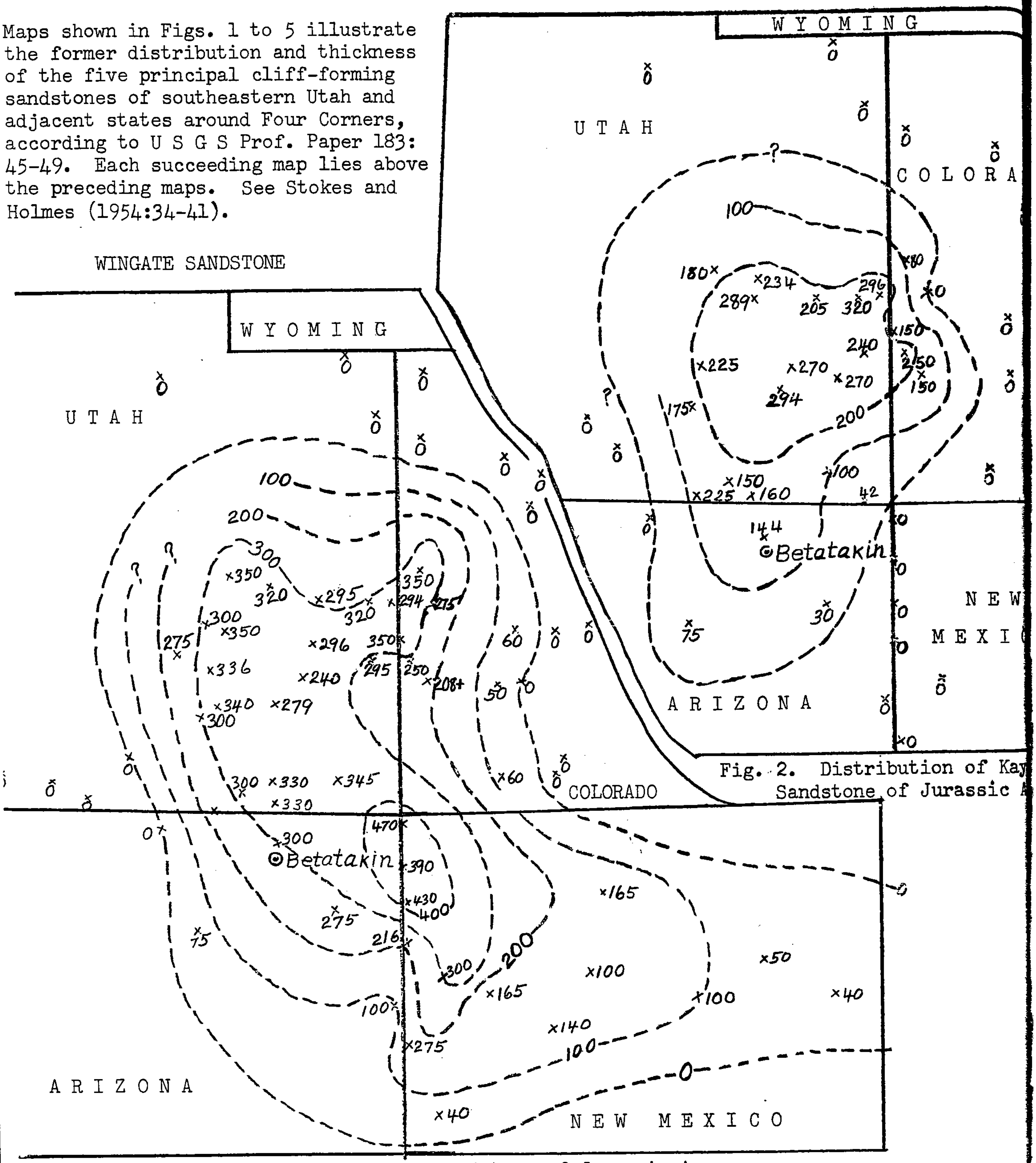


Fig. 1. Distribution of the Wingate Sandstone of Jurassic Age. U S G S Prof. Paper 183:45, and Stokes and Holmes (1954:34-41).

KAYENTA SANDSTONE

Fig. 2. Distribution of Kay
Sandstone of Jurassic A

CARMEL SANDSTONE

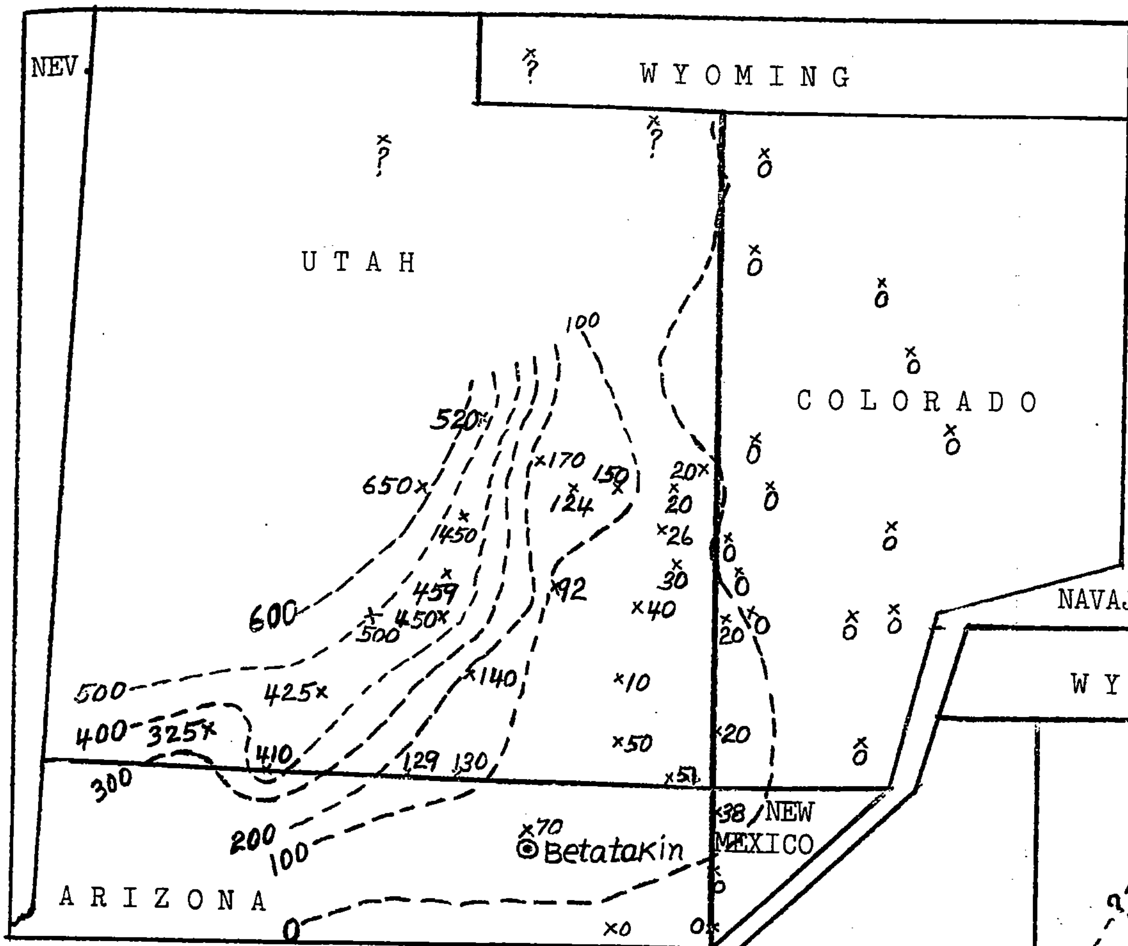


Fig. 4. Distribution of the Carmel Sandstone of Jurassic Age.

NAVAJO SANDSTONE

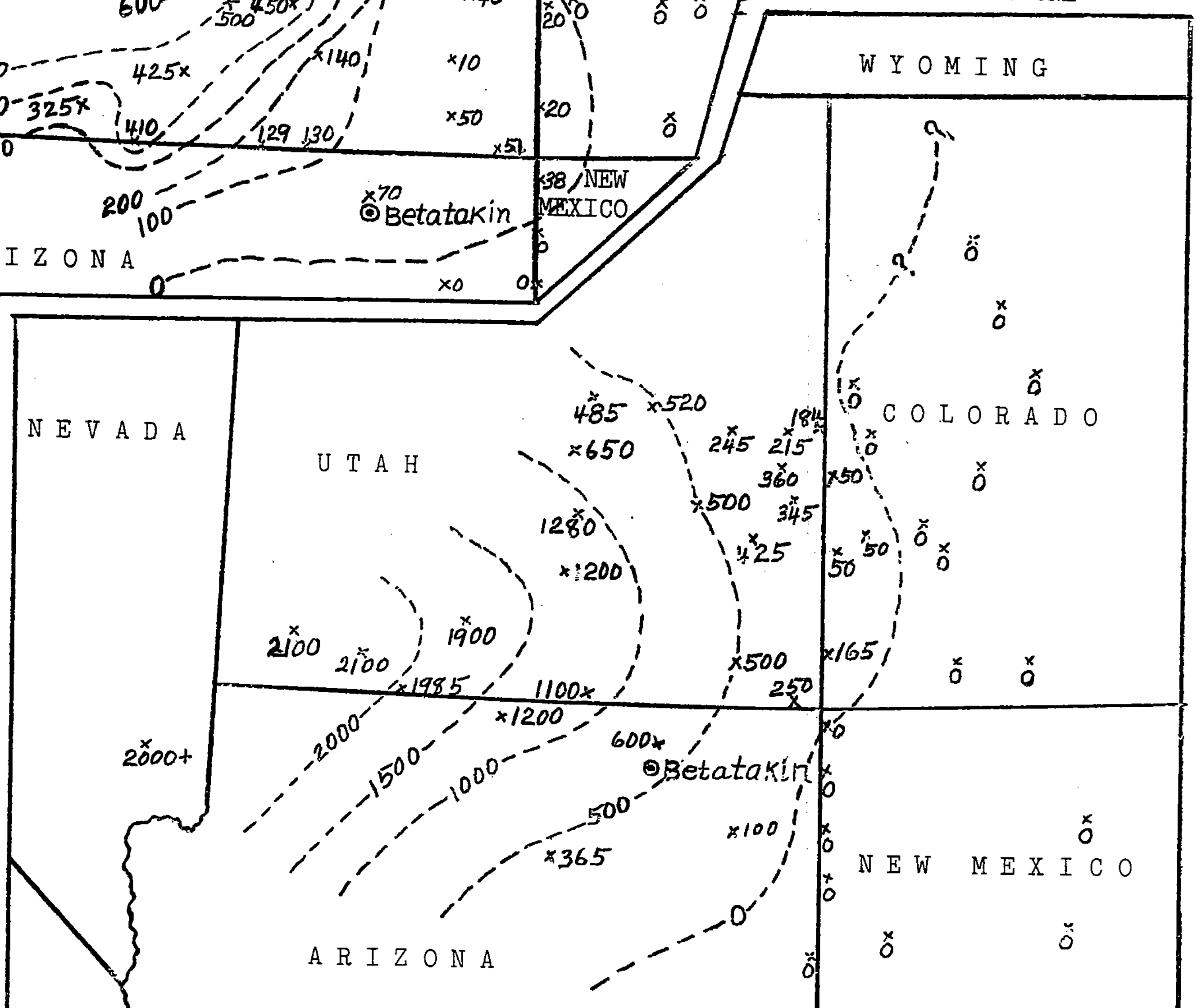


Fig. 3. Distribution of Navajo Sandstone of Jurassic Age.
U S G S Prof. Paper, 183:47, and Stokes and Holmes (1954:34-41).

ENTRADA SANDSTONE

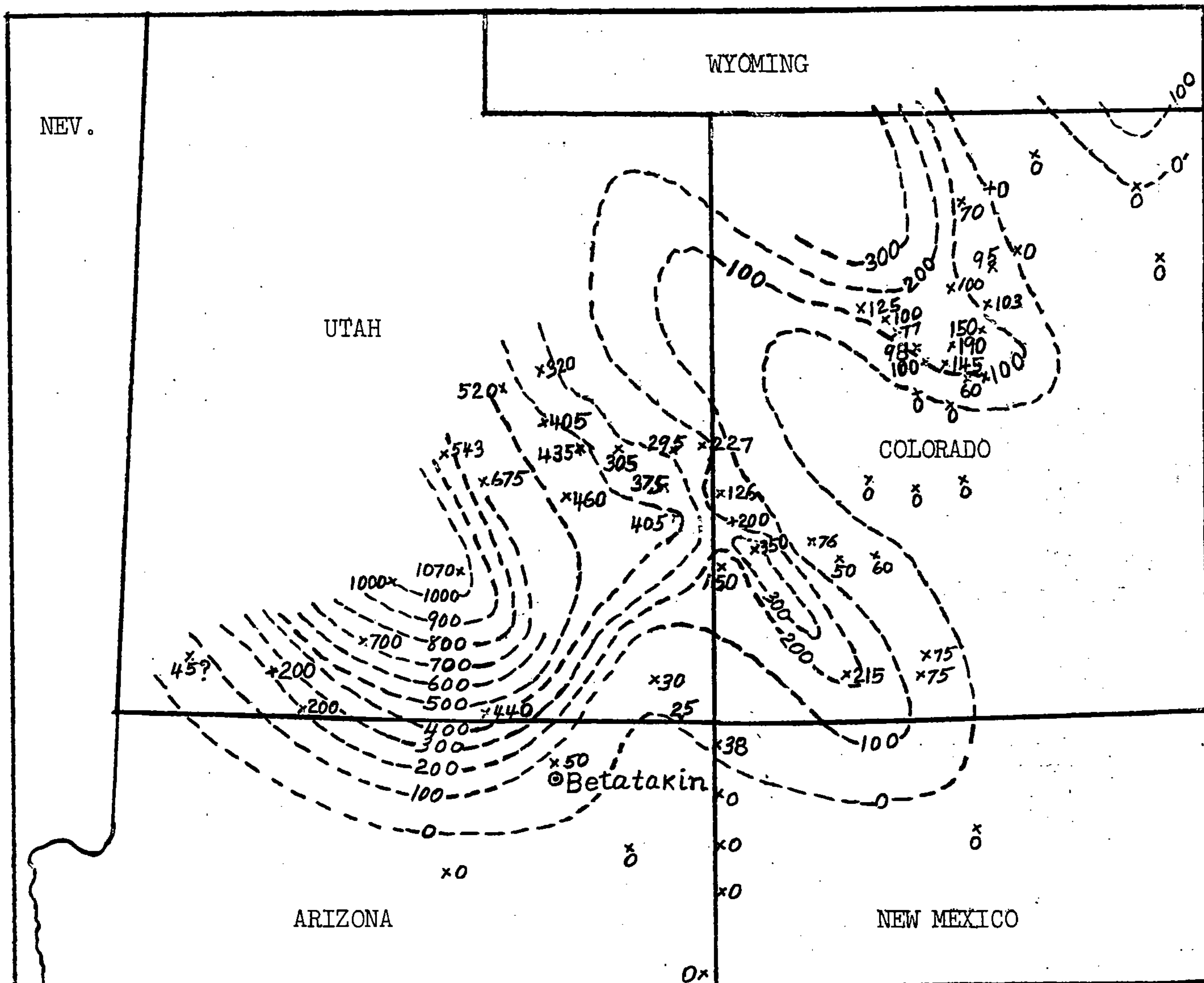


Fig. 5. Distribution of Entrada Sandstone of Jurassic Age.
U S G S Prof. Paper, 183:49, and Stokes and Holmes (1954:34-41).

and exposure to sunshine of the canyon slopes. In the temperate zone, the sides would be much alike in a north-south canyon and would differ most from each other in an east-west canyon. The northeast direction of Betatakin Canyon provides differences of intermediate proportions in the two sides.

A lone mountain such as Navajo rising high above the surrounding terrain, pierces successively less dense air at higher elevations and will in general have more intense solar radiation reaching its summit than its base. More of the re-radiation from its surface will be trapped by the denser atmosphere at lower altitudes and "hold the heat" better than that above. Furthermore, the mountain can lose nearly all of its re-radiation from the horizontal upward with little compensatory return.

In reverse, a canyon such as Betatakin, dipping steeply below the surrounding terrain, penetrates successively more dense air at lower altitudes in the canyon and will in general have less intense solar radiation reaching the bottom because of the greater "straining" action of the denser air at greater depths. With more of the earlier morning and later afternoon sunshine shut out of the canyon at successive depths, less energy is received but the denser air at the bottom traps and holds a larger proportion of that received. Furthermore, much of the re-radiation from the bottom is intercepted by the canyon walls, re-radiated from wall to wall and held below.

Since water absorbs and holds a much larger proportion of incident solar energy than rock or soil, vegetation composed mainly of water acts as a heat reservoir. Short desert vegetation cannot store much heat from sunshine and it is rapidly lost by radiation during a desert night. Larger vegetation, such as the pinyon-juniper forest on the plateau, the oaks, aspens, firs and birches of the canyon depths are able to store a larger proportion of the solar energy received during the day and maintain a relatively more constant supply of re-radiation during the night.

Despite these differences between a high mountain and a deep canyon, the total effect in determining the vegetation belting shows considerable parallelism. The pinyons and junipers characteristic of the plateau at Betatakin surround the base of Navajo Mountain and dwindle out upward on the mountain slope, Fig. 9. A similar dwindling occurs downward into the canyon at Betatakin, except as it is interrupted by the cliffs, Fig. 6.

Ascending a mountain, the brush belt usually occurs above the pigmy conifers and gives way at higher altitudes to aspen and fir or spruce conifers. In some places, the brush may be interspersed with ponderosa pines. The aspen often serves as a nurse cover for firs or spruces. In Betatakin Canyon, the pigmy conifers give way downward to oak brush and this in turn gives way to aspen downward in the bottom. The aspen here has not served as a nurse cover for firs. Douglas firs occur, however, in specially sheltered nooks at the bases of cliffs.

Where aquafers provide water for streams in the bottom, the streamsides are usually lined with clumps of birch bushes or small trees, often associated with dogwood. On terraces behind the streamside, the boxelder is not uncommon. In certain places, moist soil bears meadow-like stands of the primitive horsetails (Equisetum) and meadow rue.

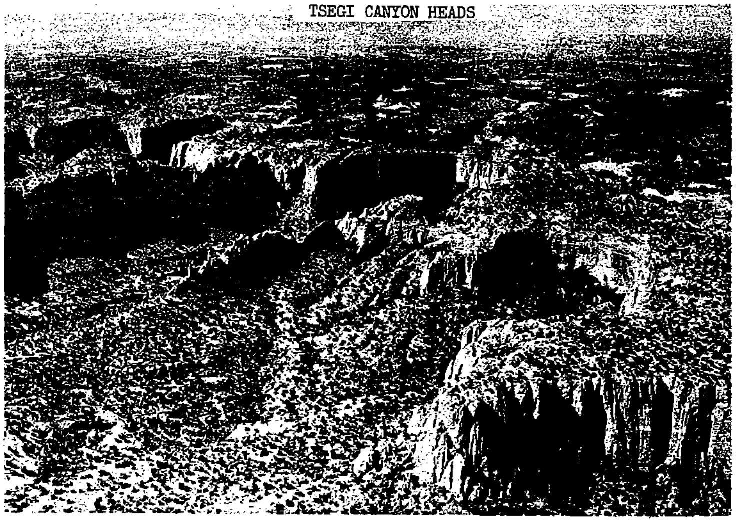


Fig. 6. Looking into Tsegi Canyon country showing pigmy conifers and sagebrush on the landscape and large conifers in sheltered nooks of canyon heads. Photo by American Exploration Society, 1937.

NAVAJO MOUNTAIN

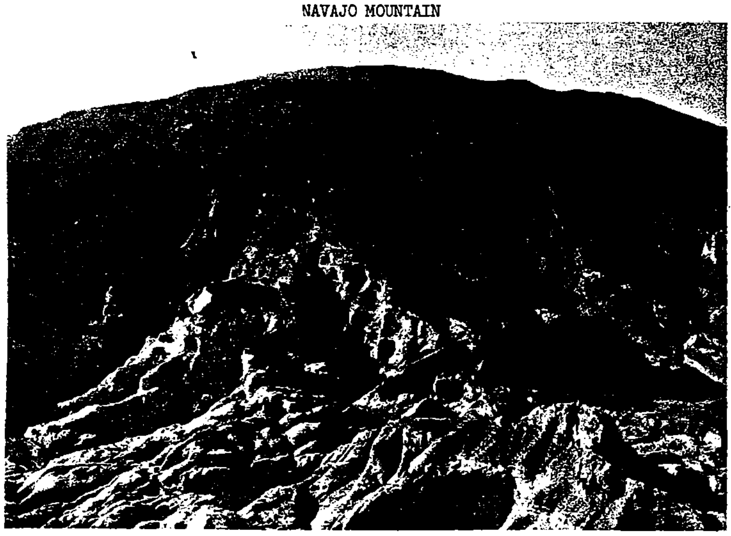


Fig. 7. A laccolithic dome, Navajo Mountain, tilting the Navajo Sandstone up the slope and subjecting it to deep canyon cutting. American Exploration photo, 1937.

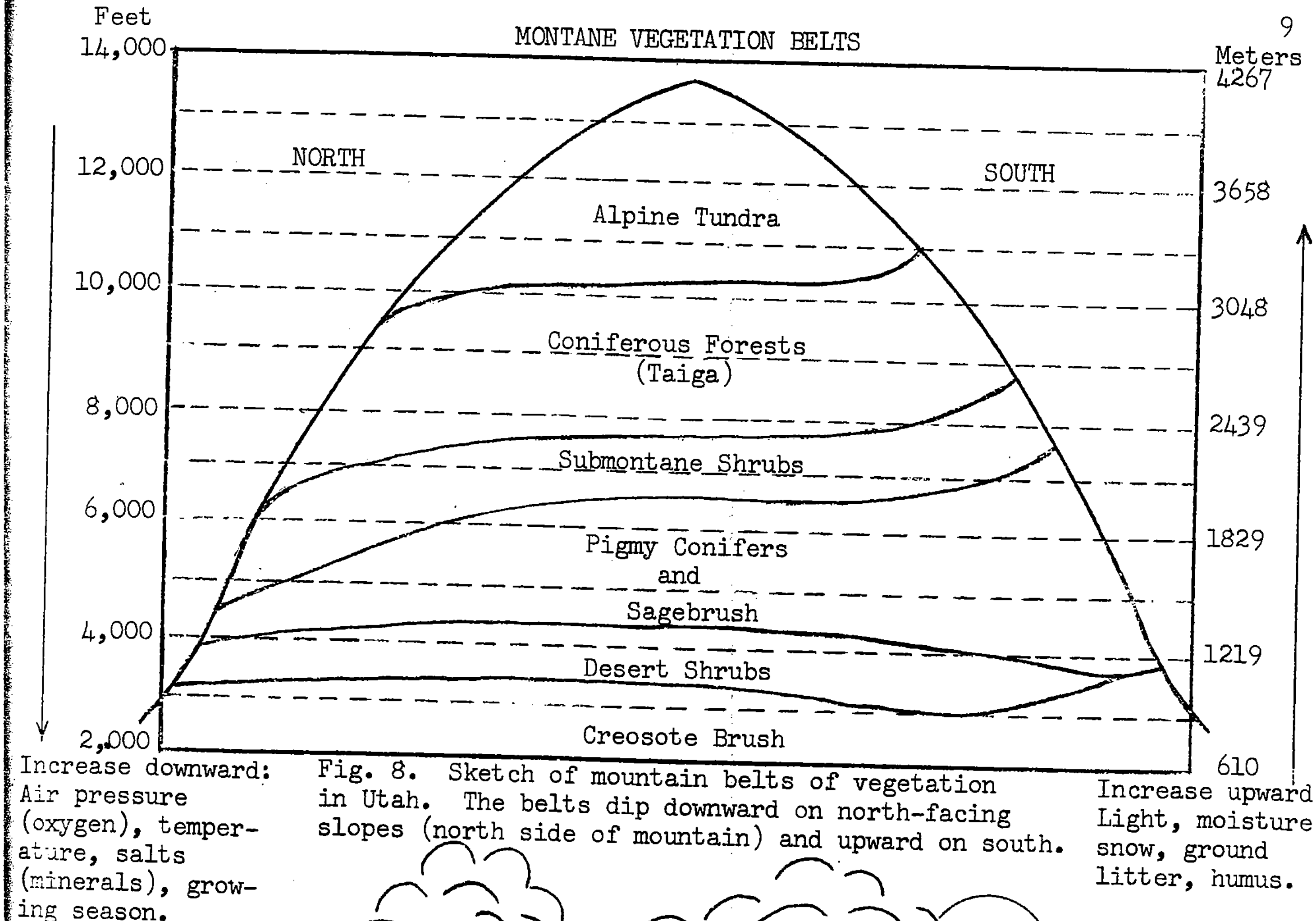
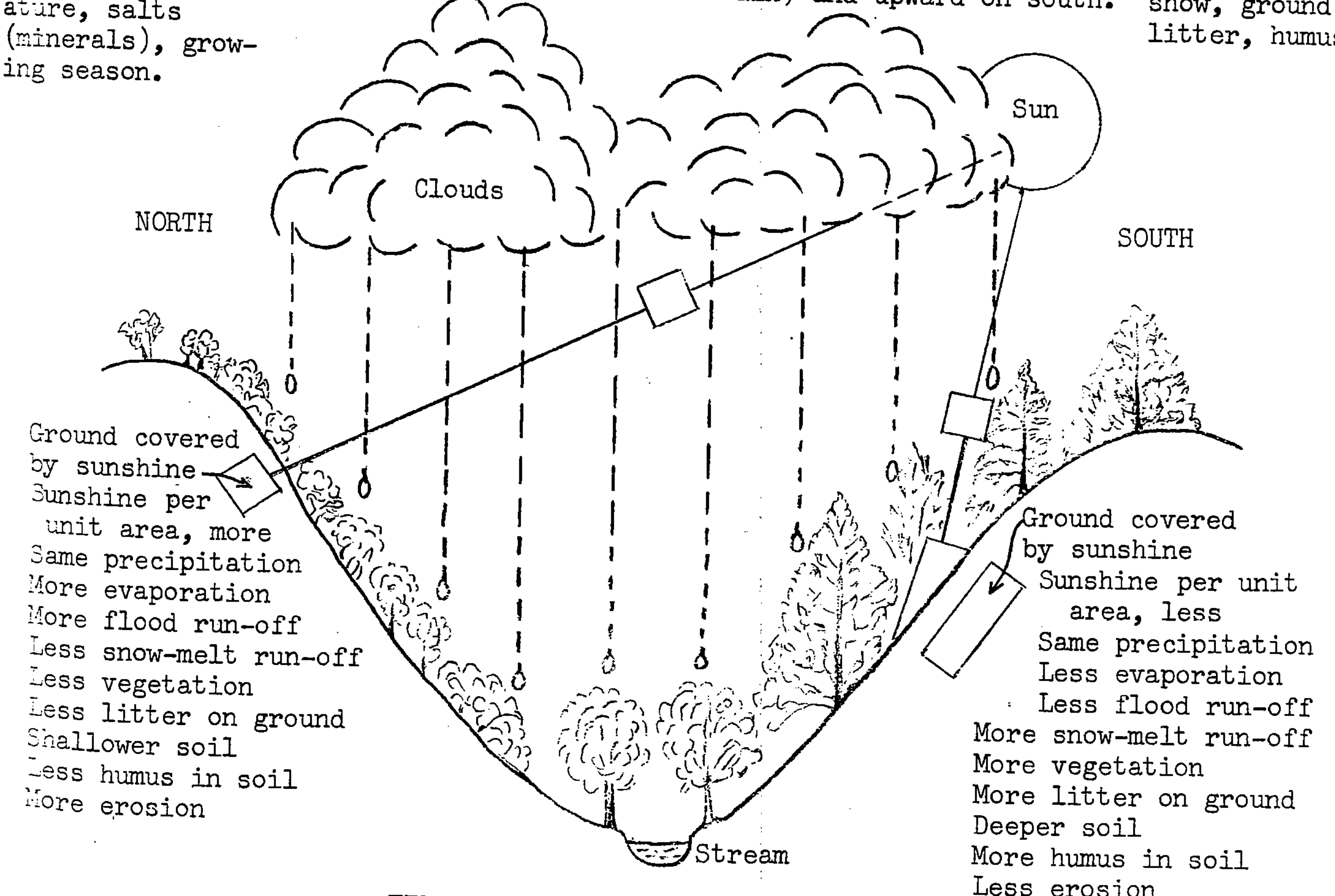


Fig. 8. Sketch of mountain belts of vegetation in Utah. The belts dip downward on north-facing slopes (north side of mountain) and upward on south.



EFFECTS OF ASPECT AND SLOPE IN CANYONS

Fig. 9. Diagram showing effects of aspect and slope on north and south-facing slopes in an east-west canyon in a semi-arid region of western United States.

INTERPRETIVE PROGRAM

The primary reason for the inclusion of Betatakin Canyon in a national monument is the presence of the archeological ruins surviving from the 11th to 13th centuries in the Betatakin overhang or cave. That ruin should properly be the central theme of the interpretive program and all other portions of the program should be designed as auxiliary support of the central theme. How a group of people could establish themselves, survive for a couple of centuries and then abandon their homes is a question requiring ecological answers concerning their physical and biological environment that permitted their survival and impelled their exit.

No doubt the cave was the central attraction that determined their home location. The overhang protected them and their buildings from overhead weather. The southeasterly facing cliff gave them a goodly portion of winter sunshine and mountain-type vegetation in the bottom of the canyon provided summer shade. The water seeps at three levels in the cave gave easy control of culinary water and the steep slope at the mouth gave easy access to their home but provided an advantage against assault from potential raiders.

These physical features providing comfort for homes would be inadequate to support the population of the cave without biological resources adequate to provide maintenance levels of food, clothing and other necessities of existence. Archeological studies of their abandoned homes indicated that their culture was based on agriculture supplemented with gatherings from natural crops of vegetation and animal life. The natural crops were doubtless essentially the same then as now. Ecological studies of the flora and fauna now present can give the clue to their gatherings of the past provided ecological changes since their sojourn can be properly evaluated.

Erosion of deep washes through the bottom of Betatakin Canyon during the early part of this century may have removed much of the land the aborigines used for agriculture. Farther down the canyon but still within reach of the cave, sagebrush terraces between meanders of the wash left undisturbed by the wash erosion may give clues or even indicate the lands formerly used for agriculture. This aspect is being studied for the National Park Service by Dr. Olaf Arrhenius, Soils Chemist, University of Stockholm, Sweden.

Draining of the canyon by wash cutting may have changed the canyon bottom and streamside vegetation in quantity and location but probably did not significantly affect its composition. Hillside and plateau vegetation would probably be little, if any, changed by that erosion. Today the wash in the bottom of the canyon is again aggrading its bed in certain places and may eventually re-build its former level.

Among gatherings from the surrounding region, outstanding today are the crops of acorns from oaks in the canyon and the pine nuts from pinyon trees of the plateau but many other less abundant items were probably available within reach of their headquarters. Then, the mule deer and rabbits probably constituted the most accessible and prolific source of undomesticated animal products but these were doubtless supplemented from many less abundant sources. Rearing of turkeys may have provided a means of harvesting natural crops of insects and of seeds by transforming them into animal products of meat, fat, bones, sinews, feathers and the like.

Interpretive Program

In planning the interpretive program, all auxiliary material should be so arranged as to contribute to this main objective of interpreting the environment in which these aboriginal people lived. For practical purposes, interpretation must be presented as far as feasible where people can observe the objects of interpretation. These will naturally occur along the roads in the monument, at the Visitor Center, and along trails developed for the purpose, Figs. 10 and 11.

MATERIALS AVAILABLE FOR INTERPRETATION

Materials available for use in the interpretive program include the archeological ruins of Betatakin Cave, Fig. 12 , the general environment of the region, Fig. 13, the geological stratification that helped determine the physiography of the aboriginal homeland, the widespread pigmy conifer forests that dominate the landscapes, Fig. 6, the patches of mountain vegetation ensconced in the deep narrow head of Betatakin Canyon, and the hidden or inconspicuous animal life associated with the landscape and vegetation.

The environment of the aborigines included not only the canyon and plateau that molded much of their activity but doubtless included surrounding areas contributing to their locale and even to distant lands where they may have gone hunting, visiting friends, pursuing enemies, exchanging products, or even exploring. Views of Navajo Mountain, Black Mesa and Skeleton Mesa would be common experiences to those who climbed out of the canyon onto the high mesa. The many deep box canyon heads of the Tsegi Canyon complex, Fig. 6, would be familiar to many of the inhabitants of Betatakin. Such views could well be included in the interpretive program.

The geological formations of Navajo, Kayenta and Wingate sandstones so plainly exposed in Betatakin and other Tsegi Canyon heads were certainly important factors influencing the topography that affected their lives so vitally. These are materials for interpretation that should be explored by geologists and included in the program. They should include the cliff-making propensities and cave formations in the Navajo, the slope-making characteristics of the Kayenta, and the weird dune stratification and cliff development of the Wingate. Comparison with modern sand dunes should be exploited.

In the biological field, primary emphasis should be given to the pigmy forests of pinyon pines and junipers (formerly called cedars in parts of the west) with the associated plants and animals. This is the outstanding phenomenon of the vegetation of the region, Fig. 6, lining the approach roads and self-guiding trails and surrounding the Visitor Center and camp grounds. This is a complex and widespread biotic community of the southwest and has many component plants and animals well adapted for association with these dominant dwarf trees.

Secondary emphasis can well be devoted to the inverted mountain vegetation within the canyon. The oaks, aspen and firs found in small quantities in the canyon furnish good contrast with the dominant pigmy conifers so common in the region. Reasons for these inverted relationships and their effects on the aboriginal inhabitants should be an integral part of the program.

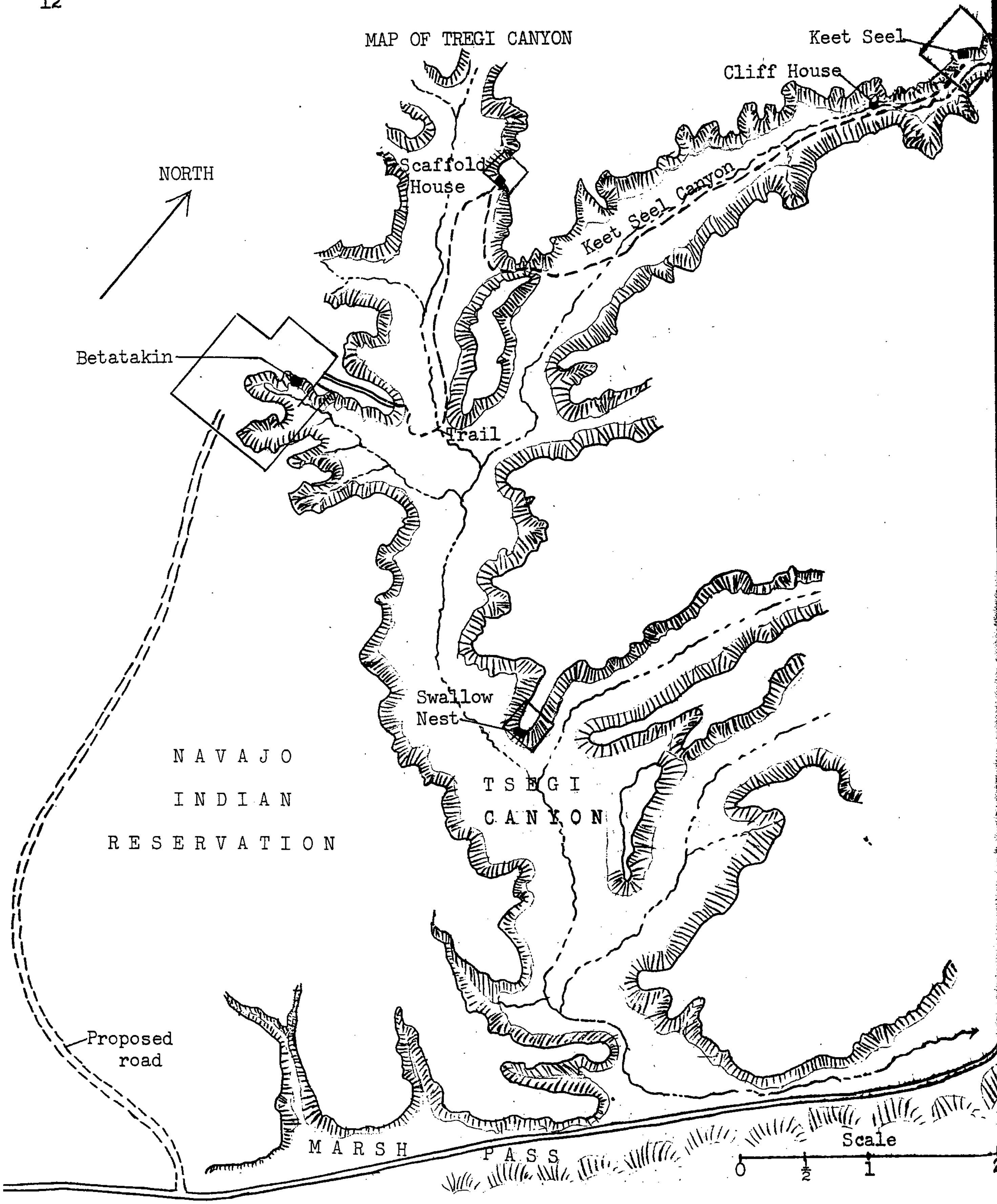
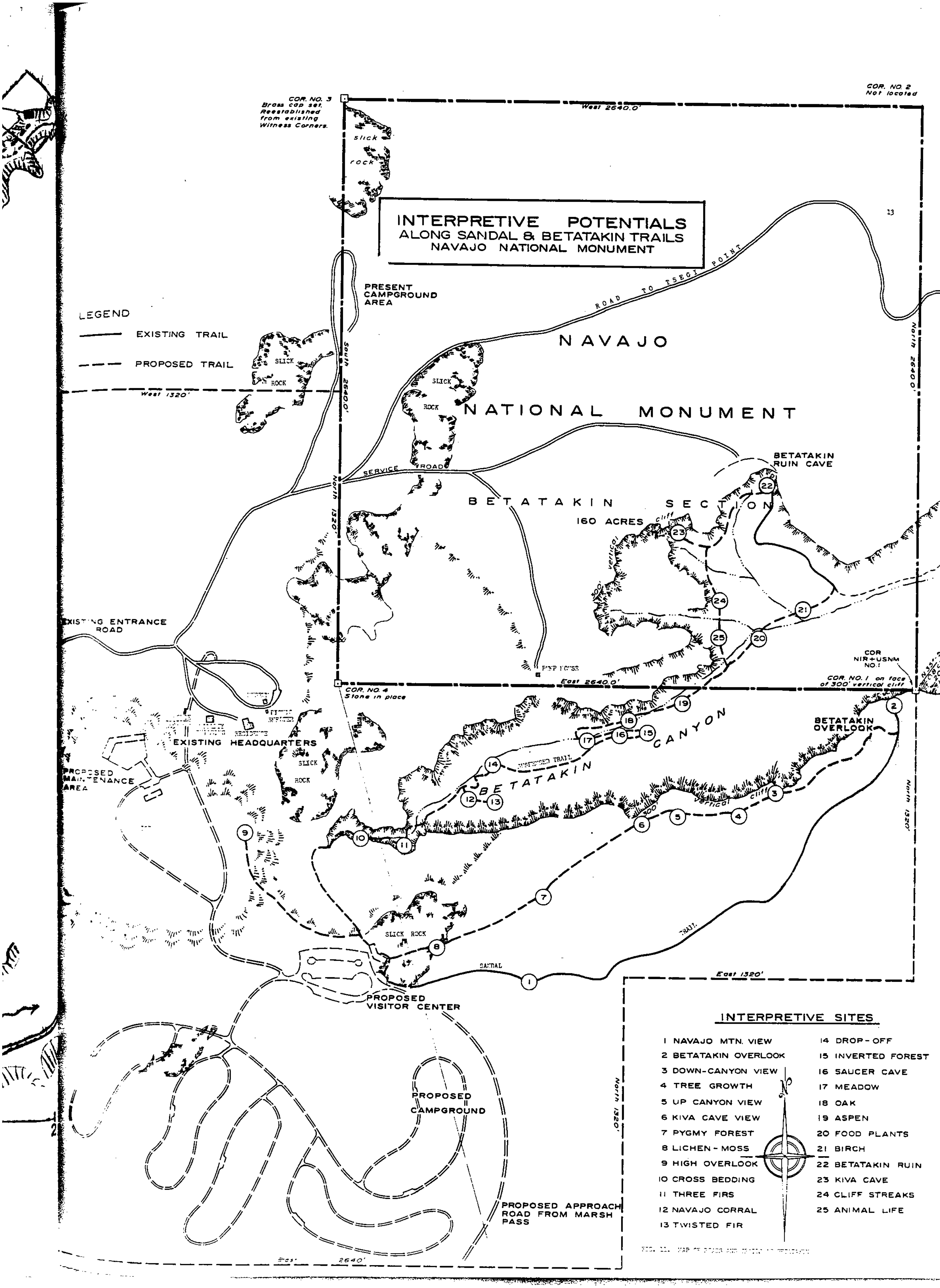


Fig. 10. Map of Tsegi Canyon showing location of ruins.



INTERPRETIVE POTENTIALS
ALONG SANDAL & BETATAKIN TRAILS
NAVAJO NATIONAL MONUMENT
LEGEND
EXISTING TRAIL
PROPOSED TRAIL
COR. NO. 3
Brass cap set. Reestablished from existing Witness Corners.
COR. NO. 2
Not located
West 2640.0'
West 1320'
South 2640.0'
North 1320'
North 2640.0'
East 2640.0'
East 1320'
North 1320'
East 2640'
slick rock
PRESENT CAMPGROUND AREA
ROAD TO TSEGI POINT
NAVAJO
NATIONAL MONUMENT
SLICK ROCK
SERVICE ROAD
BETATAKIN SECTION
160 ACRES
BETATAKIN RUIN CAVE
300' vertical cliff
EXISTING ENTRANCE ROAD
COR. NO. 4
Stone in place
COR
NIR+USNM
NO.1
COR. NO. 1 on face of 300' vertical cliff
EXISTING HEADQUARTERS
PROPOSED MAINTENANCE AREA
BETATAKIN CANYON
BETATAKIN OVERLOOK
300 vertical cliff
SANDAL TRAIL
PROPOSED VISITOR CENTER
PROPOSED CAMPGROUND
PROPOSED APPROACH ROAD FROM MARSH PASS
INTERPRETIVE SITES
1 NAVAJO MTN. VIEW
2 BETATAKIN OVERLOOK
3 DOWN-CANYON VIEW
4 TREE GROWTH
5 UP CANYON VIEW
6 KIVA CAVE VIEW
7 PYGMY FOREST
8 LICHEN-MOSS
9 HIGH OVERLOOK
10 CROSS BEDDING
11 THREE FIRS
12 NAVAJO CORRAL
13 TWISTED FIR
14 DROP-OFF
15 INVERTED FOREST
16 SAUCER CAVE
17 MEADOW
18 OAK
19 ASPEN
20 FOOD PLANTS
21 BIRCH
22 BETATAKIN RUIN
23 KIVA CAVE
24 CLIFF STREAKS
25 ANIMAL LIFE
N

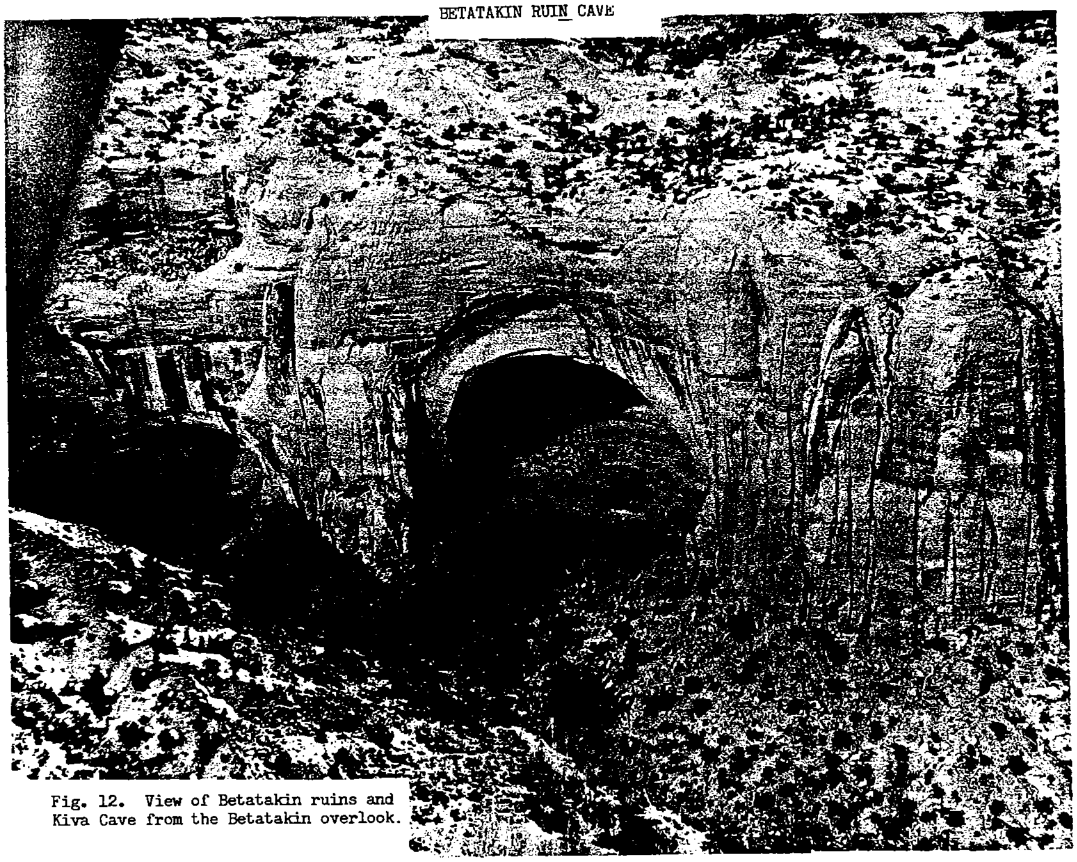


Fig. 12. View of Betatakin ruins and Kiva Cave from the Betatakin overlook.

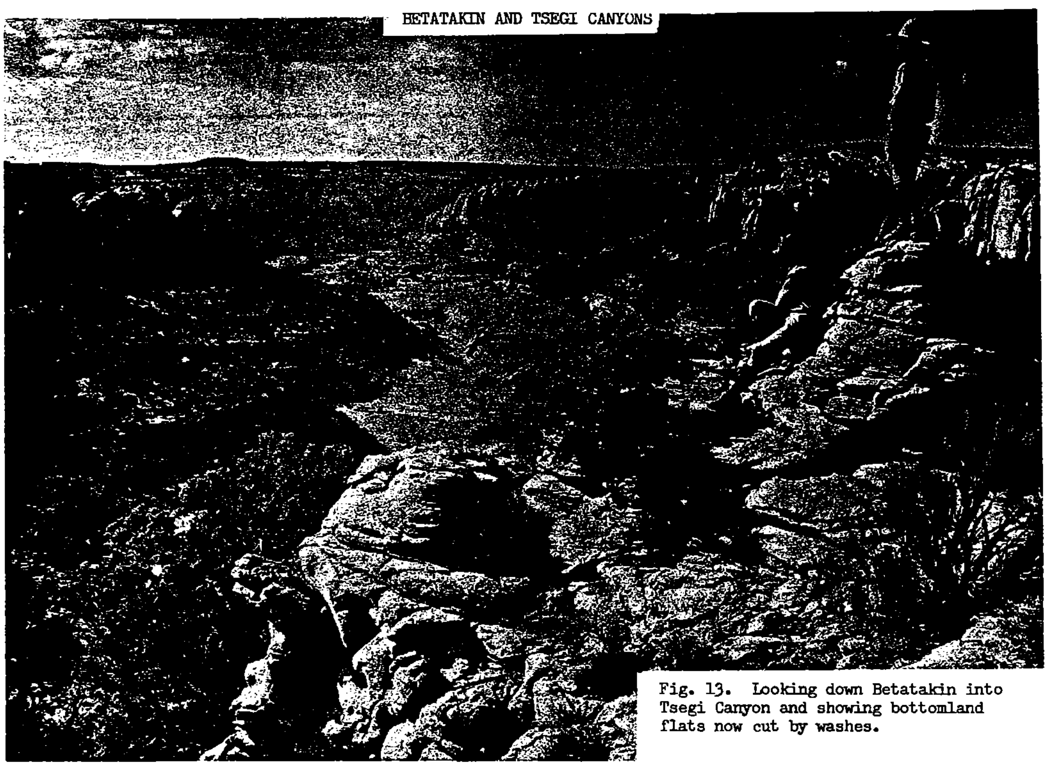


Fig. 13. Looking down Betatakin into Tsegi Canyon and showing bottomland flats now cut by washes.

PIGMY CONIFER FORESTS

The pigmy conifers of pinyon pines and junipers having a distinct ecological appearance on the landscapes of the region, Fig. 6, generally range from 10 to 30 feet in height and from about 5000 to 7500 feet or more in altitude. Within that range, they often share dominance with the big sagebrush which usually takes possession in fine grained soils of canyon bottoms and valleys while the pigmy conifers dominate the ridges and hills with coarse soil, sand or rocks, Fig. 6.

While these trees and sagebrush generally dominate the landscape, yet many other plants occupy minor niches or microhabitats between the dominant trees. Where bare rock is exposed, lichens may cover the surface and pioneer the way for moss to become established and expand. The accumulation of soil in the moss may offer a roothold for seed plants to become established and gradually encroach on the bare area. Other plants may follow one another in irregular sequence until the pigmy conifers come into possession.

Conspicuous Plants

Some of the more conspicuous members of this vegetation type at Betatakin include the following:

Pinus edulis Engelman	Double-leaf pinyon pine
Juniperus monosperma (Engelm) Sargent . .	One-seed juniper
Artemisia tridentata Nutt.	Big sagebrush
Elaeagnus argentea Pursh.	Silver buffaloberry
(or *Shepherdia rotundifolia* Parry. . . .	Silver seal)
Cercocarpus sp.	Mountain mahogany
Chrysothamnus spp.	Rabbitbrush
Cowania stansburiana Torr.	Cliff rose
Fendlera rupicola Gray.	Fendlera bush
Gutierrezia sarothrae (Pursh) Britt . . .	Matchweed
Opuntia sp.	Prickly pear cactus
Opuntia sp.	Dry-fruited cactus
Opuntia erinacea Engelm & Bigel.	Grizzly bear cactus
Opuntia whipplei Engelm & Bigel.	Prostrate cholla cactus
Echinocereus fendleri (Engelm) Rumpler. .	Hedgehog cactus
Echinomastus johnsonii (Parry) Baxter . .	Beehive cactus
Cleome serrulata Pursh.	Purple beeflower
Gilia aggregata (Pursh) Spreng.	Scarlet gilia
Pentstemon spp.	Pentstemon

Birds of the Pigmy Conifers

Birds are probably the most conspicuous element of the native fauna although lizards and insects may be more often observed. Despite its irregularities of cover, the pigmy conifer vegetation covers more area than any other cover type in the Navajo country and more birds appear to be adapted to live in that habitat than any other in the region. The following birds are permanent residents, spending the major part of their lives among those dwarf trees and seldom straying outside of their influence:

Pigmy Conifer Forests

Permanent Residents Limited to Pigmy Conifers

Gymnorhinus cyanocephalus Wied. . . . . Pinyon jay
Parus inornatus ridgwayi Richmond . . . . Plain titmouse
Psaltriparus minimus plumbeus (Baird) . . . . . . Common bushtit
Thryomanes bewickii eremophilus Oberholzer. . . Bewick wren

The following birds are breeders of the pigmy conifers, seldom, if ever, breeding in other habitats, but usually migrate elsewhere to spend the winter.

Breeders Limited to Pigmy Conifers

Phaelaenoptilus nutallii nutallii (Audubon) . . Poor-will
Myiarchus cinerascens cinerascens (Lawrence). . Ash-throated flycatcher
Empidonax wrightii Baird. . . . . Gray flycatcher
Polioptila caerulea amoenissima Grinnell. . . . Blue-gray gnatcatcher
Dendroica nigrescens (Townsend) . . . . Black-throated gray warbler

Many other birds inhabit the pigmy conifers but overflow into the other types of habitat as well. The following are permanent residents of, but not limited to, the pigmy conifers:

Residents not Limited to Pigmy Conifers

Falco sparverius sparverius Linnaeus . . . . . . Sparrow hawk
Bubo virginianus pallescens Stone. . . . . Great horned owl
Asio otus tuftsi Godfrey. . . . . Long-eared owl
Colaptes cafer collaris Vigors . . . . Red-shafted flicker
Dendrocopos villosus leucothorectis(Oberholser)Hairy woodpecker
Parus gambeli gambeli Ridgway. . . . . Mountain chickadee
Sitta carolinensis nelsoni Mearns. . . . . White-breasted nuthatch
Carpodacus mexicanus frontalis (Say) . . . . . . House finch

The following birds are breeders in, but not limited to, pigmy conifers. They usually leave in the winter.

Breeders not Limited to Pigmy Conifers

Zenaidura macroura marginella (Woodhouse). . . Mourning dove
Archilochus alexandri (Bourcier and Mulsant) . Black-chinned hummingbird
Tyrannus vociferans Swainson . . . . Cassin kingbird
Sayornis saya (Bonaparte). . . . . Say phoebe
Sialia currucoides (Bechstein) . . . . Mountain bluebird
Sialia mexicana bairdi Ridgway . . . . Western bluebird
Vireo solitarius plumbeus Coues. . . . . Solitary vireo
Spizella passerina arizonae Coues. . . . . Chipping sparrow

Wide ranging birds that cover large territories may include the pigmy conifers as part of their operations and may be found at Betatakin occasionally.

Wide Ranging Birds of Pigmy Conifers

Cathartes aura teter Friedmann . . . . Turkey vulture
Accipiter striatus velox (Wilson). . . . . Sharp-shinned hawk
Accipiter cooperi (Bonaparte). . . . . Cooper hawk
Buteo jamaicensis calurus (Cassin) . . . . Red-tailed hawk
Aquila chrysaetos canadensis (Linnaeus). . . . . Golden eagle
Falco mexicanus Schlegel . . . . Prairie falcon
Chordeiles minor henryi Cassin . . . . Common nighthawk

Many other birds, too numerous to list, may visit the pigmy conifers as migrants, wanderers, or accidentals.

DEEP CANYON VEGETATION

The mountain vegetation persisting in the head of Betatakin Canyon consists mainly of relict patches of the following plants:

Terrestrial Plants

Pseudotsuga menziesii (Mirb) Franco	Douglas fir
Populus tremuloides Michx	Quaking aspen
Quercus gambelii Nuttall	Gambel oak

Streamside Plants

Equisetum sp.	Horsetail
Betula fontinalis Sargent	Waterbirch
Cornus sp.	Dogwood
Acer interius Britt	Boxelder

Birds of the Deep Canyon

These relict patches of mountain vegetation in the head of Betatakin Canyon are so small in size by comparison with the widespread pigmy conifer forests that a full complement of animals normally associated with large areas of such vegetation should not be expected here. Small populations of certain species of closely associated birds have been observed in this vegetation but many of the species found here either overflow into adjacent pigmy conifers or are overflows from that vegetation. Birds usually associated with this type of vegetation and likely to be found here, include the following:

Birds of Deep Canyon Vegetation

Dendrocopos pubescens leucurus (Hartlaub)	Downy woodpecker
Empidonax difficilis hellmayri Brodkorb	Western flycatcher
Contopus sordidulus veliei Coues	Western wood pewee
Cyanocitta stelleri macrolopha Baird.	Steller jay
Aphelocoma coerulescens woodhousei Baird.	Scrub jay
Sitta canadensis Linnaeus	Red-breasted nuthatch
Myadestes townsendi (Audubon)	Townsend solitaire
Piranga ludoviciana (Wilson).	Western tanager
Pheucticus melanocephalus melanocephalus (Swainson)	Black-headed grosbeak
Pipilo erythrophthalmus erythrophthalmus Swarth	Rufous-sided towhee

Birds Overflowing from Pigmy Conifers

Zenaidura macroura marginella (Woodhouse)	Mourning dove
Colaptes cafer collaris Vigors.	Red-shafted flicker
Dendrocopos villosus leucothorectis (Oberholser).	Hairy woodpecker
Parus gambeli gambeli Ridgway	Mountain chickadee

Birds of Cliffs, Ledges and Boulders

Bubo virginianus pallescens Stone	Great horned owl
Strix occidentalis lucida (Nelson).	Spotted owl
Aeronautes saxatalis saxatalis (Woodhouse).	White-throated swift
Petrochelidon pyrrhonota (Vieillot)	Cliff swallow
Corvus corax sinuatus Wagler.	Common raven
Catherpes mexicanus conspersus Ridgway.	Canyon wren
Salpinctes obsoletus obsoletus (Say).	Rock wren

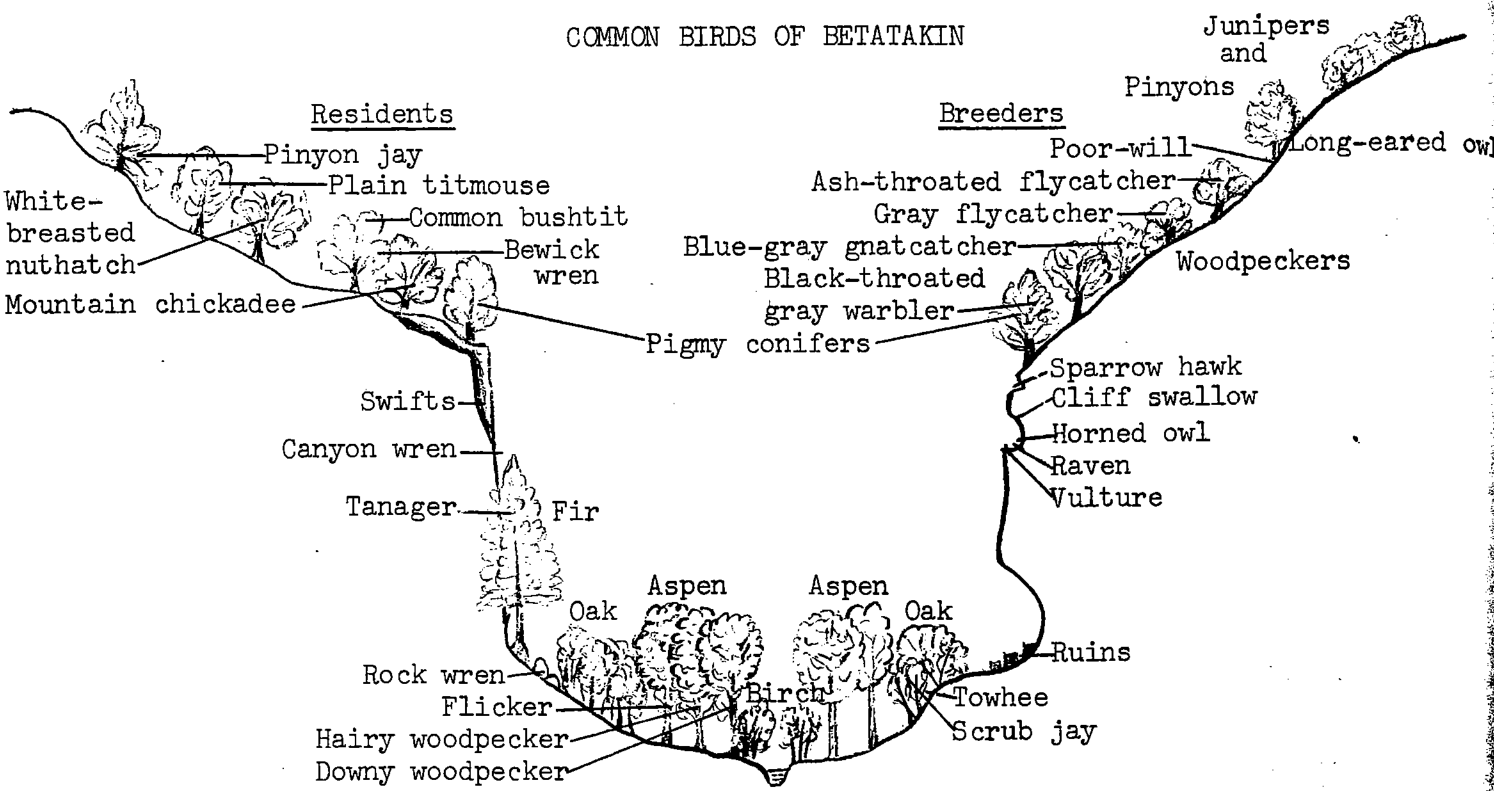


Fig. 14. Sketch of Betatakin Canyon showing ecological setting of common vegetation and common birds.

OTHER ANIMALS OF BETATAKIN

The highly mobile birds that can fly over the landscape and see the various habitats available have an advantage in making their choice of niches they inhabit than the less mobile animals that must travel the land surface and cannot skip over unsuitable habitat by flight. For this reason, these vertebrates will be treated in a general way without specific integration with the vegetation.

AMPHIBIANS

The amphibians are associated at some time in their lives with water. In this southwestern desert where water is very scarce, the known amphibians are associated with small streams, ponds or temporary pools widely spaced in the desert. In Betatakin, the principal source of such water is in the springs and small streams in the depths of the canyon and in temporary pools in the slick rock or in potholes in the bottom of washes. A salamander and three toads have been found at similar places in the surrounding region and should occur at Betatakin. The salamander is known from Cow Springs and the three toads from Shonto. The salamander seldom strays far from water even in the adult stage but the toads may spread from the breeding ponds where the tadpoles are reared long distances into surrounding range where they hide underground during winter and dry weather and emerge when it rains. Those expected to be here are the following:

AMPHIBIA (class) . . . . Amphibians

Ambystomidae (family) . . . . Mole salamanders
Ambystoma tigrinum nebulosum Hallowell. . . . Arizona tiger salamander

Pelobatidae (family) . . . . Spadefoot toads
Scaphiopus hammondi hammondi Baird. . . . Hammond spadefoot

Bufonidae (family) . . . . Toads
Bufo punctatus Baird and Girard. . . . Red-spotted toad
Bufo woodhousei woodhousei Girard. . . Rocky Mountain toad

REPTILES

Our reptiles are free from the requirement of water for breeding purposes and only the garter snake which lives around aquatic habitats is associated with water. All of the other snakes and lizards obtain water in their food supplies and have behavior patterns that help them conserve this supply so they do not ordinarily drink in nature. The reptiles expected to be found in the Tsegi Canyon system, including Betatakin, include the following:

REPTILIA (class) . . . . Reptiles

LIZARDS

Iguanidae (family) . . . . Iguanid lizards
Crotaphytus collaris auriceps Fitch and Tanner . . . . Yellow-headed collared lizard
Usually associated with open rocks and boulders from pigmy conifers downward.

Reptiles

<u>Crotaphytus</u> <u>wislizenii</u> <u>wislizenii</u> Baird and Girard . . . Leopard lizard
Usually associated with sand below pigmy conifers and may occur in Tsegi Canyon branches.

<u>Holbrookia</u> <u>maculata</u> <u>approximans</u> Baird . . . . Speckled earless lizard
Found in the lowland flats of Klethla Valley and may occur in the low bottoms of Tsegi Canyon branches.

<u>Phrynosoma</u> <u>douglassi</u> <u>hernandesi</u> Girard . . . . Mt. short-horned lizard
Well distributed through pigmy conifers and lower lands.

<u>Sceloporus</u> <u>undulatus</u> <u>elongatus</u> Stejneger . . . . Northern plateau lizard
Usually associated with cliffs and rocks from pigmy conifers downward.

<u>Sceloporus</u> <u>graciosus</u> <u>graciosus</u> Baird & Girard. . . Sagebrush lizard
As common name indicates, it is usually associated with sagebrush.

Teidae (family) . . . . Whiptails and racerunners

<u>Cnemidophorus</u> <u>tigris</u> <u>septentrionalis</u> Burger . . . Northern whiptail
This checkered or spotted lizard is usually associated with open flats or sandy areas.

<u>Cnemidophorus</u> <u>sacki</u> <u>innotatus</u> Burger . . . . Plateau whiptail
This striped lizard overlaps the habitat of the preceding spotted lizard but usually occurs at slightly higher elevations and may be found in Betatakin Canyon.

SNAKES

Colubridae (family) . . . . Colubrid snakes

<u>Thamnophis</u> <u>elegans</u> <u>vagrans</u> Baird & Girard. . . . Wandering garter snake
Found on Laguna Creek west of Kayenta and could well extend up the Tsegi Canyon to Betatakin.

<u>Masticophis</u> <u>taeniatus</u> <u>taeniatus</u> Hallowell. . . . Desert striped whipsnake
Well distributed through the region and could well occur at all levels at Betatakin.

<u>Pituophis</u> <u>catenifer</u> <u>deserticola</u> Stejneger. . . . Great Basin gopher snake
A dry land snake that could occur in pigmy conifers or in Betatakin Canyon.

<u>Lampropeltis</u> <u>getulus</u> <u>californiae</u> Blainville. . . . California kingsnake
Variety <u>boylii</u> B & G, found near Tuba City and might be found in Betatakin Canyon.

<u>Crotalus</u> <u>viridis</u> <u>nuntius</u> Klauber . . . . Hopi rattlesnake
This is the small pink rattler of lowland sandy areas.

<u>Crotalus</u> <u>viridis</u> <u>viridis</u> Rafinesque . . . . Prairie rattlesnake
This has a greenish tinge and usually occurs at intermediate or higher altitudes, known in the Tsegi system only from a small area near Swallow Nest, $3\frac{1}{2}$ miles above Marsh Pass (Milton Wetherill).

MAMMALS

Among the mammals, only the bats can, like the birds, fly over many habitats and select the ones they prefer. They are mostly nocturnal foragers through air spaces for food and retire to suitable secluded shelter for rest in the daytime. Most of them prefer dark caves, cracks or crevices in cliffs. Since Betatakin Canyon is well supplied with daytime retreats and provides a generous supply of night-flying insects from the dense vegetation in the canyon, it is to be expected that most of the bats endemic in the southwest will occur here. Dr. S. D. Durrant has estimated that the following bats should be present:

MAMMALIA (class) . . . . Mammals

CHIROPTERA (order) . . . Bats

Vespertilionidae (family) . . . . Vespertilionid bats
- *Myotis volans interior* Miller . . . . Long-legged myotis
- *Myotis californicus stephensi* Dalquest. . . . . . California myotis
- *Pipistrellus hesperus hesperus* (A. Allen) . . . . Western pipistrelle
- *Eptesicus fuscus pallidus* (Young) . . . . Big brown bat
- *Corynorhinus townsendi pallescens* Miller. . . . . Big-eared bat
- *Antrozoas pallidus pallidus* (LeConte) . . . . . . Pallid bat

RABBITS

The most commonly observed mammals on the landscape are the rabbits. They occur almost everywhere but are probably not as common in heavy forests as in the more brushy or open habitats. Jack rabbits which live on the surface and hide in the daytime in special "forms" or shelters are usually active at night and are more conspicuous in the evening or early morning. The cottontails that usually retreat to burrows in the daytime are usually more secretive than the jack rabbits and not so conspicuous. Betatakin is within the range of the following rabbits that should be found here. Of the two cottontails that are likely to overlap in habitat, the Nuttal is likely to be found at slightly higher elevations than the Audubon.

LAGOMORPHA (order) . . . . Rabbits and allies

Leporidae (family) . . . . Rabbits
- *Lepus californicus texianus* Waterhouse. . . . . Black-tailed jack rabbit
- *Sylvilagus nuttallii pinetus* (J. A. Allen). . . Nuttall cottontail
- *Sylvilagus audubonii warreni* Nelson . . . . Desert cottontail

RODENTS

Most numerous of all the mammals in this region are the rodents although many of them, especially the nocturnal species, are seldom observed in nature. All of the local rodents, except the porcupine, use underground burrows. Of those that do, all except the pocket gopher, habitually forage above ground and retreat to the burrow for shelter, rest and nesting. Ordinarily, they control small territories around their burrows. Many of them are nocturnal foragers and are hidden in their burrows in the daytime. Those that are active in the daylight, mainly the squirrels, chipmunks, and prairie dogs, may be conspicuous elements of the fauna on the landscape. The following rodents are estimated by Dr. Durrant to occur in this region although some of them may not be found in the monument.

RODENTIA (order) . . . . Rodents

Sciuridae (family) . . . . Squirrels and allies
- _Cynomys gunnisoni zuniensis_ Hollister. . . . Gunnison prairie dog
- _Citellus spilosoma cryptospilotus_ (Merriam). Spotted ground squirrel
- _Citellus variegatus grammurus_ (Say). . . . . Rock squirrel
- _Citellus leucurus cinnamomeus_ (Merriam). . . White-tailed antelope squirrel
- _Eutamias cinereicollis cinereicollis_ (Allen) Gray-collared chipmunk

Geomyidae (family) . . . . Pocket gophers
- _Thomomys bottae aureas_ Allen . . . . Valley pocket gopher

Heteromyidae (family) . . . . Kangaroo rats and allies
- _Perognathus flavus hopiensis_ Goldman . . . . Silky pocket mouse
- _Perognathus apache apache_, Merriam . . . . . Apache pocket mouse
- _Perognathus intermedius crinitus_ Benson. . . Rock pocket mouse
- _Dipodomys ordii longipes_ (Merriam) . . . . . Ord's kangaroo rat

Cricetidae (family) . . . . Native rats and mice
- _Onychomys leucogaster pallescens_ Merriam . . Northern grasshopper mouse
- _Reithrodontomys megalotis megalotis_ (Baird). Western harvest mouse
- _Peromyscus crinitus auripectus_ (Allen) . . . Canyon mouse
- _Peromyscus maniculatus rufinus_ (Merriam) . . Deer mouse
- _Peromyscus maniculatus sonoriensis_ (LeConte) Deer mouse
- _Peromyscus boylii rowleyi_ (Allen). . . . . . Brush mouse
- _Peromyscus truei truei_ (Shufeldt). . . . . . Pinyon mouse
- _Peromyscus difficilis nasutus_ (Allen). . . . Rock mouse
- _Neotoma stephensi relicta_ Goldman. . . . . . Stephen's woodrat
- _Neotoma albigula laplataensis_ F. W. Miller . White-throated woodrat
- _Neotoma cinerea arizonae_ Merriam . . . . . . Bushy-tailed woodrat

Erethizontidae (family) . . . . American porcupines
- _Erethizon dorsatum couesi_ Mearns . . . . . . Porcupine

CARNIVORES

In contrast with the rabbits and rodents, which are mainly vegetarian or insectivorous in diet, are the carnivores of this region that are primarily predators on vegetarians. In general, the rabbits and rodents have a higher rate of reproduction than the carnivores and supply extra numbers beyond those needed to maintain themselves that can be harvested by the carnivores as prey without disrupting the prey populations. Most of the predators of this region concentrate attention upon capturing rabbits and rodents but others are concerned mainly with the ungulates to be treated next in this sequence.

In general, carnivore population numbers will be regulated largely by the numbers of surplus prey that they can harvest. In turn, they exert a regulating pressure upon prey population numbers, but it must not be assumed that they are the only regulators. Weather, parasites, diseases, food supplies and many other lesser factors play their parts in helping to regulate population numbers, relegating the influence of predators to an important place in a series of controls.

Human experience has shown that one of the most efficient ways of increasing the crop of wild game for human taking is the reduction of predators so that man can harvest what the predators would otherwise take. A small area like Navajo National Monument cannot be managed on national park standards, independent of control practices in surrounding areas. It is entirely possible that reduction of predators outside may allow undue increases of prey within that cannot be controlled without human intervention. This is a problem that will need attention over the years.

The case history of the Kaibab Game Preserve in Kaibab National Forest is a good example that may be useful in interpretive planning. When set aside as a game preserve in the first decade of this century, deer populations were exceedingly low. A concerted campaign against deer predators, mountain lions, coyotes and wild cats, brought such rapid resurgence of deer populations that within the third decade deer were so numerous they were overgrazing their range, destroying much of the vegetation cover, and starving to death by the thousands on their winter range. Such a startling change brought reversal of policies and provided for human hunting to save a smaller population of deer from the carnage of heavy over-populations.

Dr. Durrant has estimated that the following carnivores may occur in the region but some of them may not be found in Betatakin Canyon:

CARNIVORA (order) . . . . Carnivores

Canidae (family) . . . . Coyotes, foxes and allies
Canis latrans mearnsi Merriam. . . . . Coyote
Urocyon cinereoargenteus scotti Mearns . . . Gray fox

Procyonidae (family) . . . . Raccoon allies
Bassariscus astutus arizonensis Goldman. . . Ringtail

Mustelidae (family) . . . . Weasels and allies
Mustela nigripes (Audubon and Backman) . . . Black-footed ferret
Spilogale putorius gracilis Merriam. . . . . Spotted skunk

Felidae (family) . . . . Cats
Lynx rufus baileyi Merriam . . . . Bobcat

UNGULATES

Heavy grazing of domestic sheep in suitable areas around the monument certainly reduces the potential grazing capacity for native wild ungulates in the region and the small area within the monument is not likely to affect this potential significantly. The only wild ungulate that would occur naturally inside the monument is the mule deer but it has doubtless been exterminated in this part of the Navajo Country. It is estimated by mammalogists that the natural range of the pronghorned antelope included some of the desert flats in this region, but it has also doubtless been exterminated here. These two ungulates listed below were probably present during aboriginal times.

ARTIODACTYLA (order) . . . . Even-toed ungulates

Cervidae (family) . . . . Deer and allies
Odocoileus hemionus crooksi (Mearns). . . . Mule deer

Antilocapridae (family) . . . . Pronghorn
Antilocapra americana americana (Ord) . . . Pronghorned antelope

INVERTEBRATES

Invertebrates have not been well studied in this region. It is known in a general way that there is a large population of insects, numerous arachnids, a few millipeds, centipeds, and crustaceans, and several mollusks inhabiting the monument. Local mollusks are associated with dense or medium dense vegetation, most of them inhabiting moist litter under trees or bushes. Among other arthropods, centipeds may be found under stones almost any place but millipeds are likely to be more limited, like the mollusks, to moist litter, mainly under the deep canyon vegetation. Insects may be found in practically all habitats, aquatic and terrestrial. Isopods are likely to be limited to moist litter habitats but other crustaceans occur in streams or ponds, at least one in temporary pools that fill after rainstorms.

MOLLUSKS

Most mollusks are associated with water or moist habitats but a few are adapted to medium or mesic conditions of moisture in the habitats they occupy. None is adapted to live in the severe deserts of the southwest. The driest habitat occupied is likely to be that under juniper trees in the pigmy conifers probably occupied by a species of *Pupilla*. The deep canyon vegetation in Betatakin is a veritable oasis for snails which live mainly in the shady litter under trees and bushes. Those known to occur here in the canyon, collected by Milton Wetherill and Angus M. Woodbury (specimens at University of Utah) in 1938 include the following:

GASTROPODA (class) . . . . Snails

Helicidae (family) . . . . Helix snails
Vallonia pulchella (Muller). . . . . Smooth midget snail

Pupillidae (family) . . . . Columnar snails and relatives
Vertigo coloradensis (Cockerell) . . . . Colorado columnar snail

Achatinidae (family)
Cochlicopa lubrica (Muller) . . . . Fusiform snail

Zonitidae (family) . . . . Leaf snails and allies
Vitrina alaskana Dall . . . . Alaskan glassy snail
Vitrea indentata (Say) . . . . Indented leaf snail
Euconulus fulvus alaskensis (Pilsbry). . . . . Conical leaf snail
Zonitoides arborea (Say) . . . . Tree snail

Endodontidae (family)
Gonyodiscus cronkhitei (Newcomb) . . . . Cronkhite snail
Gonyodiscus cronkhitei anthonyi (Pilsbry). . . Anthony snail

CRUSTACEANS

Crustaceans are mainly marine organisms but some are freshwater forms and a few of the isopods have achieved terrestrial existence under humid conditions. Adaptations that permit use of aquatic gills for breathing in air include gill covers that help protect them from desiccation, living in humid habitats, activity when humidity is high, and curling into a ball (pill bug) during dry conditions.

Crustaceans

Freshwater forms are common in most streams and they sometimes occur in small streams or springs of desert regions, especially where dense aquatic vegetation provides suitable habitat. The following are known to occur in this region and may occur at Betatakin.

CRUSTACEA (class) . . . . Crustaceans
Data from Stanley Mulaik

ISOPODA (order) . . . . Isopods (pillbugs)

There are no known native isopods in this region but exotic species are known to follow modern human extension. There were probably none in Betatakin when the aborigines lived there but may have been introduced since then. There are probably none in the pigmy conifers but some species may be found in the litter under the vegetation in the deep canyon.

Armadillidiidae (family)
Armadillidium vulgare Latreille 1804
A ubiquitous isopod found almost everywhere and widely distributed in Arizona and Utah, likely to be found at Betatakin.

Porcellionidae (family)
Cylisticus convexus De Geer 1778
Associated with human activities mainly in streamside vegetation under litter and logs and likely to occur in the deep canyon.

Metaponorthus pruinosus (Brandt) 1853
Another widespread homophile likely to occur in Betatakin.

Porcellio laevis Latreille 1804
Occurs throughout Arizona and southern Utah.

Porcellio scaber Latreille 1804
Known from Utah and Arizona; it should be here.

NOTOSTRACA (order)

Apodidae (family)
Apus longicaudus LeConte. . . . Tadpole shrimp
One of the puzzles of the American southwest, it is found in temporary pools and playa lakes almost everywhere, active when water is present, disappearing when dry. Specimens were taken from a pool in the slick rock above the canyon on Sept. 21, 1962, the next day after it rained and filled the pool. Its life history is not known.

AMPHIPODA (order) . . . . Scuds and allies

Talitridae (family)
Hyallela knickerbockeri (Bate) 1862
Widely distributed in springs and small streams of surrounding region and may be expected in aquatic vegetation in small streams in the deep canyon.

Gammaridae (family)
Gammarus fasciata Say
Like the preceding, it may be found in aquatic habitat of Betatakin.

MILLIPEDS

Millipeds are in general very sensitive to low moisture conditions and are not abundant in desert areas. They occur mostly in the vicinity of springs and streams, under dense vegetation, or in caves of certain types. Being slow moving creatures of sedentary habits, they have in the course of time responded by adaptation to factors of isolation to a remarkable degree and species are often restricted to very limited areas or to a single oasis or canyon. It is probable that distinctive forms may be found in the dense vegetation of Betatakin Canyon.

In desert areas, most species burrow into deep litter or into the ground during dry weather, sometimes to considerable depths and remain dormant until a rain or fresh stream activates them and they regain the surface. Millipeds are often missed in general collecting but special attention to hunting them at different seasons of the year, especially in the spring when soils and litter are moist or after a storm that has brought them to the surface may bring to light forms that are now unknown.

So far as known, little collecting of millipeds has been done in Betatakin but the following are known to occur in this region or in neighboring areas and are suspected of occurring here. There may be others.

Millipeds have developed special adaptations that help protect themselves from many marauders that would otherwise prey upon them. One of these adaptations is a chemical that is capable of generating poisonous cyanide gas. The chemical substance stored in a chamber can be released through a valve into a chamber containing a catalyst that generates the gas. This passing out through an opening above each leg is an effective repellant to ants and other would-be predators.

DIPLOPODA (class) . . . . Millipeds
Data from R. V. Chamberlin

JULIDA (order) Chamberlin 1938

Paraiulidae (family) Bollman 1893
<u>Aniulus bollmani</u> Causey 1952
A widespread species known from Arizona and Utah as well as more eastern states may be represented here.

<u>Taijulus tiganus</u> (Chamberlin) 1910
A common Utah milliped inhabiting streamside vegetation may extend into Arizona.

CHORDEUMIDA (order) Chamberlin 1943

Rhiscosomididae (family) Sylvestri 1909
<u>Tingupa</u> Chamberlin 1910
A species of this genus may be represented at Betatakin.

Lysiopetalidae (family) Wood 1865
<u>Colactis</u> Loomis
Species of this genus occur in Arizona in narrow geographical ranges. One may be represented here.

SPIROBOLIDA (order) . . . . Cylindrical millipeds

Atopetholidae (family) Chamberlin 1918

<u>Arinolus</u> Chamberlin 1940

Members of this genus are common in Arizona where they seem prone to speciation under conditions of isolation and are likely to be represented in Betatakin. Other genera may also be represented here.

CENTIPEDS

As centipeds are carnivorous and free ranging in habit, the species are usually more widely distributed than the millipeds and do not show as much restrictions to local ranges. They are usually easy to find and are generally well known. Like other desert invertebrates, they are generally restricted by lack of moist habitats but are free to move around to find suitable places. Ordinarily, they are active at night or after storms when humidity is most favorable in preventing desiccation. The following centipeds probably occur in the region and may be found at Betatakin.

CHILOPODA (class) . . . . Centipeds
Data from R. V. Chamberlin

SCOLOPENDRA (order)

Scolopendridae (family)

<u>Scolopendra</u> <u>polymorpha</u> Wood. . . . The centiped

This large form, well known throughout the southwest as "the centiped" is likely to be found at Betatakin

Geophilidae (family)

Members of this group are commonly found in leaf litter or underlying soil.

<u>Geophilus</u> <u>rubens</u> Say

This wide-ranging species occurs across the United States and is likely to occur in this region.

Chilenophilidae (family)

<u>Arctogeophilus</u> <u>xenoporus</u> (Chamberlin)

Common in Utah as far south as Washington and San Juan counties and may extend southward into Arizona.

Himantariidae (family)

<u>Gosiphilus</u> <u>minor</u> <u>arizonicus</u> (Chamberlin)

LITHOBIIDA (order)
Short fast moving centipeds, commonly collected.

Henicopidae (family)

<u>Lamyctes</u> <u>pinampus</u> Chamberlin

A western species known from southern Utah and may extend into Arizona.

Gosibiidae (family)

<u>Gosibius</u> <u>arizonicus</u> Chamberlin

Known from Arizona and southern Utah.

Centipeds

Lithobiidae (family)
  Lithobius arizonae Chamberlin
    Ranges from Arizona into San Juan and Washington counties, Utah.

  Oabius sanjuanus Chamberlin
    Known from the San Juan River banks.

  Tidabius tivius Chamberlin
    Widespread across the country; known from San Juan County and adjacent areas.

Ethopolidae (family)
  Archepolys gosobius Chamberlin
    Known from southeastern Utah and may extend into Arizona.

INSECTS

Insects are so ubiquitous and so varied that they may be found in all habitats - pigmy forest, deep canyon, rocks and cliffs, and springs or streams of water. They are certain, when better studied, to include species of nearly all the major groups ranging from the simple primitive wingless forms through intermediate stages of life histories passing through incomplete metamorphosis such as eggs, nymphs, and adults, to complete metamorphosis of eggs, nymphs, pupae, and adults, and even to hypermetamorphosis in which the nymphs have several specialized forms.

They will also include species that range the gamut of feeding, from aquatics that feed in the water and terrestrial forms that feed on vegetation through predators to parasites and hyperparasites. No attempt will be made to identify the species that may occur at Betatakin. Only some general considerations of major groups will be given.

Aquatic Insects

Some of the major groups of insects are primarily aquatic organisms in their developmental stages, but several of the major orders that are primarily terrestrial, have aquatic representatives. Aquatic insects usually spend their nymphal or larval and their pupal stages in the water but emerge into the air for reproduction in their adult stage. A number of aquatic bugs and beetles are aquatic in the adult stage also but carry bubbles of air with them for use in their air-breathing apparatus. Those primarily aquatic groups include the mayflies (Ephemeroptera), the dragonflies (Odonata), the stoneflies, (Plecoptera), and the caddisflies (Trichoptera). There is a probability that each of these orders may have one or more representatives in the stream of the deep canyon. Adult dragonflies are not uncommon and are conspicuous inhabitants of the landscape. Others may require careful observation to find.

Aquatic representatives of terrestrial orders are likely to be found among the bugs (Hemiptera), the moths (Lepidoptera), the beetles (Coleoptera), and the two-winged flies (Diptera). In 1958, collecting in the tributaries of the Colorado River in Glen Canyon yielded specimens of 7 species of mayflies, 13 dragonflies, and 8 caddisflies among the aquatic orders and 11 species of bugs, one moth, 23 beetles, and 18 two-winged flies (Smith, Musser and McDonald, 1959:186-193). Since Betatakin lies within the drainage system into Glen Canyon, there is a probability that representatives of these groups will be found in the stream in the deep canyon and some may even occur in temporary pools.

Terrestrial Insects

Representatives of the primitive wingless insects, the springtails (Collembola), and possibly of the bristle-tails (Thysanura) probably occur in many places especially in the litter under vegetation. Most of them are so small that they are easily overlooked.

The grasshoppers, crickets and allies of the order Orthoptera are certain to be more obviously represented. Grasshoppers are likely to be encountered in almost every habitat on warm summer days as they hop or flutter in the air but the crickets (Gryllidae), praying mantids (Mantidae), and the walking sticks (Phasmidae) are likely to be concealed among the living vegetation or the litter under it, while the "bald-headed" sand cricket, (Stenopelmatus) is likely to be buried in the soil or sand in the daylight and abroad at night.

Termites (Isoptera) are not well adapted to desert conditions and may not be plentiful, if not absent, in the pigmy conifers and desert but should be common in the dense vegetation of the deep canyon, especially in dead and decaying logs or smaller litter.

There will be many species of bugs that are vegetarians, especially among the families of the stink bugs (Pentatomidae), the chinch-bugs (Lygaeidae), the leaf bugs (Miridae), and lesser numbers of such families as squash bugs (Coreidae), stilt bugs (Neididae), lace bugs (Tingidae), and other smaller groups. These have the mouthparts adapted as a tube for sucking juices and pierce plant leaves, flowers or stems to get the sap. In addition, there are numerous species that suck the liquids (blood) from animals. Some of them feed on small invertebrates, including other insects while others feed on vertebrates, such as reptiles, birds and mammals, including man. These include the well known kissing or assassin bugs (Reduviidae), damsel bugs (Nabidae), ambush bugs (phymatidae) which are camouflaged to look like flowers and ambush other insects that come there for nectar, and the small pirate bugs (Anthocoridae) that feed on small plant lice (aphids).

Among the closely related homopterans (Homoptera) that also have sucking mouthparts and many have the whole wing transparent instead of only one half as in the Hemiptera, there may be ample representation here of plant lice (aphids), leafhoppers (Cicadellidae), treehoppers (Membracidae), spittlebugs (Cercopidae), and cicadas (Cicadidae). These are mostly small insects except the cicadas which are conspicuous both in size and in song. These spend their larval and pupal stages underground, in some cases remaining there for years before emerging as adults. Plant lice may be found at times on almost any of the common plants. Other kinds may be less common and more difficult to find unless they occur in irruptive numbers when the hoppers may look like a swarm as you pass through them.

There may be a few representatives of the nerve-winged neuropterans, especially of the lacewings and the antlions. The conical craters of the larvae of the latter are very conspicuous in fine sandy areas, especially in protected places under overhanging rocks or ledges. The delicate lacewings sometimes collect around lights at night.

Perhaps the most numerous representatives will be found among the beetles. Here will be several species of metallic (Buprestidae) and long-horned (Cerambycidae) wood borers that bore as larvae into many kinds of trees; leaf beetles

(Chrysomelidae) that eat the soft parts out of leaves; flower, fruit and seed beetles of different families; bark beetles (Cucujidae, Scolytidae) that eat the cambium layer under the bark; ground beetles (Carabidae) and darkling ground or stink beetles (Tenebrionidae); root beetles whose larvae live underground (Scarabaeidae); and many other groups that are mostly plant feeders. In addition, there are many predaceous forms that feed on other insects or other invertebrates, such as the ladybug beetles that feed on many kinds of insects, the tiger beetles (Cicindelidae), scavenger beetles such as the dermestids (Dermestidae), several groups of predaceous aquatic beetles, and many other groups with specialized adaptations.

Among the Lepidoptera, there will be representatives of many families of butterflies and moths although few species have been collected and identified. A few that are known to occur in the region and may occur here include representatives of the following families: the beautiful swallowtail butterflies, the sulfur and white butterflies whose larvae are great agricultural pests, the brush-footed butterflies, the lycaenid butterflies, the familiar hawk moths, tiger moths, measuring worm moths, snout moths, gelechid moths and many others.

Among the two-winged flies, we can expect a few pestiferous mosquitoes, gnats, deerflies, snipeflies, flesh flies, tachinid flies, and muscid flies. There may be many species of the mimicking beeflies, pugnacious robber flies, attractive flower flies, and ephydrid flies. Lesser numbers of many other families will no doubt occur here. There may be a few species of parasitic flies of birds and mammals and these same vertebrates may harbor many species of parasitic fleas.

Among the four-winged hymenopterans, there will be many representatives of the ichneumons, wasps, bees, ants and allies. Most numerous will probably be the colonial ants found almost everywhere. Other numerous kinds will include the vespid paper wasps, the sphecid digger wasps, spider wasps, burrowing wasps, mining bees, leaf-cutter bees and honey bees. There may also be large numbers of ichneumon, braconid and chalcid parasites. Lesser numbers representing many other families may also be expected.

ARACHNIDS

Arachnids are primarily predaceous or parasitic forms with specialized mouthparts adapted for crushing and extracting the juices (blood) from small invertebrates or adapted for sucking blood from vertebrates. Spiders occur in almost every habitat and many of them are revealed by their webs even if they themselves are inconspicuous. Scorpions are usually active at night and are usually hidden in the daytime under rocks, logs or other shelter.

Solpugids of the order Solpugida are ferocious-looking tiny monsters that make their marauding expeditions at night when they are seldom observed by human eyes. They are widely distributed throughout the western states from Washington to Texas but are poorly known because so few specimens have been collected. They are almost certain to occur at Betatakin and any specimens found should be collected and preserved for scientific study. They may represent poorly known or new species.

Several species of parasitic ticks and numerous species of mites may be found on local vertebrates but they are not often likely to be observed in nature. Some of them are human pests and it is probable that the aborigines were plagued with them. Free-living mites occur in the litter under almost all plants.

ECOLOGY OF THE ABORIGINAL INHABITANTS

If it is assumed that landscapes today are the product of continuing natural processes of the past, the physiographic setting of the aboriginal inhabitants could not have been vastly different from the landscapes of today. There is little doubt that the canyon, the cliffs, the cave, the springs of water, the pigmy conifer forest, the deep canyon vegetation, and associated animals were essentially the same then as now, except for minor changes wrought by the natural processes of erosion, biotic modifications and human activities.

Among the natural processes of erosion affecting the landscape are (1) carrying silt from the land surface by rains and melting snows into streams that carry it away, (2) erosive cutting of washes or stream banks by floods, (3) undermining cliff bases by erosion of softer rocks and consequent spalling of the cliff face, (4) development of alcoves and caves by water emerging from cliffs, (5) covering rock faces with desert varnish, (6) blowing of sand and silt by winds, and many other processes.

Among the biotic modifications affecting the landscape are (1) covering the rock surfaces with lichens and mosses, (2) rooting of plants in soil and rock crevices that help to anchor the soil in place, (3) covering the surface with litter that helps to hold precipitation and prevent run-off, (4) shading the ground and slowing evaporation, (5) grazing the vegetation by animals, (6) trampling the litter into the soil by animals, (7) opening holes and turning the soil by burrowing animals and plant roots, (8) concentrating soil fertility in the surface layer, and many other processes.

Among post-aborigine human-associated activities that have affected the landscape at Betatakin are (1) heavy livestock grazing, especially in surrounding areas, (2) a cycle of wash-cutting erosion that lowered the stream bed leaving partial terraces of the former level, (3) exerting grazing pressure on palatable plants that reduces their proportion in the plant cover and gives emphasis to non-palatable plants, (4) reducing populations of many animals through food competition, (5) local extermination of the ungulates, deer, and prong-horned antelope, (6) reduction of carnivores by hunting and trapping and many other practices.

How much these landscape-changing processes have affected the Betatakin scene is not known and can only be accurately evaluated by careful investigation but a rough overall assessment indicates that (1) the agricultural lands used by the aborigines have reverted to natural vegetation or been washed away by wash-cutting erosion, (2) many rockfalls have broken away from the cliff faces, (3) aboriginal trails have been covered by erosion or overgrown with vegetation, (4) composition of the vegetation and associated animals have changed in minor undetermined ways, except for (5) extermination of the ungulate deer and antelope and reduction of their predators and (6) perhaps in other ways.

The most direct evidence of the ecology of the aborigines could be derived from artifacts found in the Betatakin ruins, but since they are not available, it will have to be deduced from (1) comparable data from other sources, (2) from present day ecological knowledge, and (3) assessment of potential value of biological resources by comparison with uses of similar resources by modern Indians in the region.

Ecology of Aborigines

Although those aboriginal people were gardeners raising maize (corn), beans, cucurbits, cotton, and turkeys, they were otherwise partly dependent upon and closely associated with the native flora and fauna. It is certain, therefore, that they must have been annoyed, infected, or infested with obnoxious pollens, diseases, pests, or parasites that may have been reservoired in or transmitted by native plants and animals. They must also have been affected directly by great fluctuations in the natural crops of native food plants, game, or other plants and animals utilized by them. Some of these major fluctuations activated by long-range weather conditions may have been instrumental in forcing the final evacuation of Betatakin probably prior to A. D. 1300.

The separation of Betatakin from other similar centers of culture in this region practically insures that there was a good deal of isolation, especially in the exchange of products. Commerce of any kind must have been limited to things that could be carried on the person since they had no beasts of burden nor wheeled vehicles. Travel into the Tsegi Canyon system was much easier than climbing the cliffs onto the plateau.

Betatakin lies in a region with a semi-arid climate where only the high mountains or deep canyons receive enough precipitation to maintain a dense cover of vegetation. The lower lands of the region have desert characteristics, sparse desert gray vegetation, dry washes, sharp physiographic features, blowing sand, and vivid green lines of thrifty foliage along streamsides. The gray desert plants usually show special characteristics adapted to parsimonious use of water, such as wax-coated leaves, protective hairs, leaves reduced in size or transformed into spines. Betatakin lies at an intermediate altitude where desert adaptations are not so severe.

The arid climate of the region is due largely to the nature of the winds that bring so little moisture with them and yield little precipitation. The general climate is characterized by low rainfall, low relative humidity, little cloudiness, great intensity of sunshine in summer, and great variations in temperature. It is well understood that precipitation ordinarily increases with altitude but the rate of increase is affected by other factors, especially physiography, winds, humidity and temperature. The precipitation and altitude at 18 stations in the surrounding region based upon U. S. Weather Bureau records up to 1957 have been plotted in Fig. 15 to show deviations from the assumed straight line relationships. Where Betatakin fits into the pattern is not known but it is probable that the bottom of the canyon would receive more precipitation than the line in the graph indicates for its altitude, probably as much as that received on the plateau in which it is cut. The pattern is probably little different from that affecting the aborigines.

Studies of the physiography, terrain, and climate give the impression that aboriginal populations must have been limited largely by the limited area available for agriculture or horticulture, the sparse crops gatherable from the native plants and animals, and the pests, parasites, and diseases that affected them. The amount of land available for agriculture will require further investigation to determine. The other factors can be estimated in a general way from other sources of information.

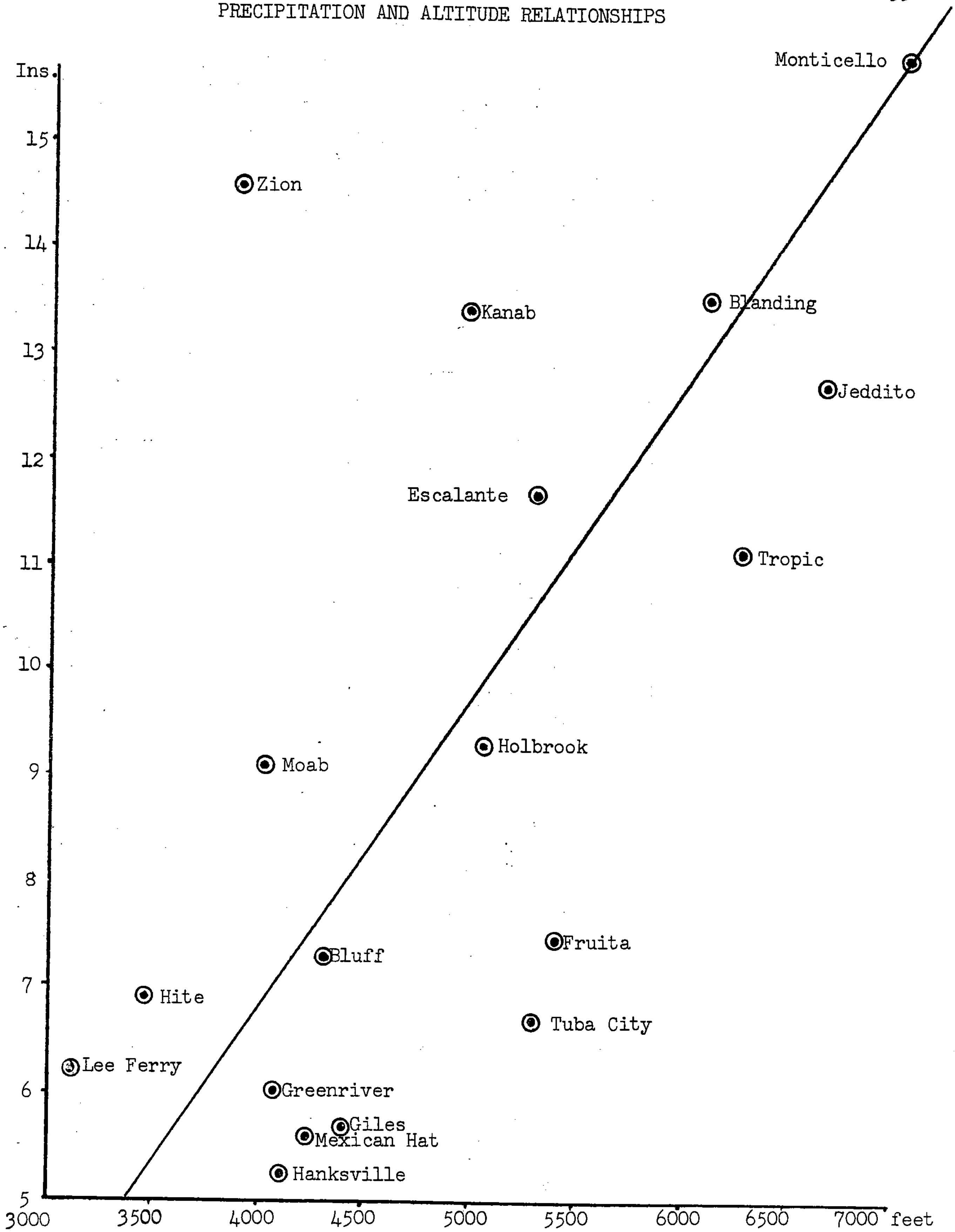


Fig. 15. Graph showing deviations of weather station records from assumed straight line relationships between altitude and precipitation.

OBNOXIOUS POLLENS

Extrapolating from the effects of windborne pollens upon people of today, it seems probable that a small percentage of the aborigines may have suffered alllergic reactions from inhaled pollens of their time. As will be shown later, most of the pollen-disseminating plants of today were present at that time. The amount and kinds of pollen in the air (Peck, 1959:1-16) varies a great deal from time to time, from place to place, and from proximity of one type of vegetation to that of another type. There is little or no pollen in the air during the winter. It generally appears in the spring, rises during the summer and tapers off in the fall.

The wind pollinated junipers and pinyon pines being the most widespread dominant plants of this area probably supply more pollen in season than any of the other plants in the general region. In the deep canyon, however, the aborigines would be more closely associated with the oaks, aspens, and birches and with willows, rabbitbrush and sagebrush farther down the canyon. These major sources of pollen would appear through the season approximately in the following order from spring to fall: juniper, aspen, willow, oak, pines, rabbitbrush and sagebrush. Lesser quantities of pollen from many other plants would mix with or overlap these major producers.

PARASITES

From studies of parasites in Utah made at the University of Utah indicate that endoparasites among native amphibians, reptiles, birds and mammals include nematodes, tapeworms, flukes, spiny-headed (acanthocephalan) worms, blood parasites, and intestinal protozoans; ectoparasites include fleas, lice, ticks, and mites; and the so-called free-living parasites include blood-sucking flies and flesh flies. In the Navajo Country, it is known that modern Indians are infected with protozoans, tapeworms and liver flukes. These are known to include the protozoan, Giardia lamblia (treatment atabrine); the dwarf tapeworm, Hymenolepis nana; and the sheep liver fluke, Fasciola hepatica. Others may also affect human beings.

Ectoparasites are relatively sparse on amphibians, reptiles and insects but abundant on birds and mammals with their coverings of feathers or fur. In western Utah deserts, lizards were found to harbor two, and snakes four species of mites but no lice, fleas or ticks. On birds, the ectoparasites included five species of ticks, 60 species of lice, at least 38 species of mites, and two species of fleas. On mammals, they included at least eight species of ticks, 13 species of lice, 23 species of mites, and 19 species of fleas (unpublished ms.). The majority of these ectoparasites will not infest man, but a small minority will and it is almost certain that the aborigines were heavily infested with lice, ticks and possibly mites and fleas. It is well known that the Navajos in the same region today are infested with the human louse and that wood ticks are common pests now as they must have been when the aborigines were living here.

They were doubtless pestered with free-living, blood-sucking two-winged flies such as the biting midges (Ceratopogoniidae), black flies (Simuliidae), snipe flies (Rhagionidae), and tabanid flies (Tabanidae). These all breed in wet places along streams or meadows and might have occurred along the stream in the bottom of the canyon. They were probably serious pests.

In addition, the robust bot flies (Cuterebridae) and flesh flies (Sarcophagidae) lay eggs where the newly hatched larvae can penetrate the host and develop as flesh parasites under the skin of the vertebrate hosts, some of which may be human children. Some of the blow flies (Calliphoridae) also parasitize vertebrate hosts but most of the local species infest carcasses or decaying matter and produce offensive odors. The tachinid flies (Tachinidae or Larvaevoridae) are similarly parasitic in invertebrate hosts, often in other insects such as grasshoppers. One of the sarcophagid flies occurring in this region, Wolfahrtia opaca, lays its eggs on young animals including human children and the hatchlings penetrate the skin. Two of the calliphorid screw worms, Callitroga americana and C. macellaria, lay their eggs in cuts or wounds where the skin is broken. Other calliphorid blow flies lay their eggs on meat or dead carcasses, so it must have been difficult for the aborigines to keep meat from being "fly blown" and infested with maggots. These pests, scavengers, and parasites abundant around their home sites and in their food must have made life difficult and required constant vigilance to protect themselves and their food from these insect depredations.

ENDEMIC DISEASES

It is well known that skeletons of pre-Columbus days have shown the effects derived from the diseases of tuberculosis, arthritis, syphilis, and possibly rickets and may have affected these people here. Broken bones have also been detected. Diseases that did not affect the skeleton would of course not be evident and knowledge of them must be obtained from other sources. It is also well known that certain diseases endemic in na tive animals today may be transmitted to man.

A few diseases have been known from ancient times but the big majority are discoveries of this and the previous century and more are continuing to be discovered at the present time. Presumptions of disease among the aborigines must be deduced from this short background of present day knowledge. For example, ornithosis formerly known as psittacosis, a disease transmitted by birds was at first assumed to have been spread from South America by parrots and parakeets shipped over much of the world, but since it has recently been found in so many birds in so many places, it seems necessary to assume that it was already a disease of wide distribution.

Among the more important diseases inherent in animals of the southwest today that may be transmitted to man and were almost certainly endemic here at the time of the Betatakin aborigines are tularemia, coccidioidomycosis, leptospirosis, spotted fever, Q fever, Colorado tick fever, and rabies. A few that may be debatable include anthrax, brucellosis, western equine encephalitis (blind staggers), and St. Louis encephalitis. Such diseases as plague, cholera, smallpox, measles and glanders are not included because they are assumed to have been introduced in post-aboriginal times.

Tularemia caused by the bacterium, Pasteurella tularensis, is a widespread disease known from many parts of the world. In the west, it is reservoired mainly in ticks but is known to occur naturally in rodents, rabbits, ungulates and many species of birds. Local rodents and rabbits that get it usually live only a few days. It may be transmitted to man by handling infected game animals, by infected tabanid fly and mosquito bites, and by infected ticks. It is not likely to pass from one person to another. It is almost certain that the aborigines would have been exposed to this disease by any of those methods.

Brucellosis caused by bacteria of the genus Brucella and known as undulant fever in man is best known from its manifestation in livestock. It is known to occur in domestic goats in the Navajo Country and in big game such as deer and in wild rodents including wood rats that are prevalent in this region. It is clearly probable that the aborigines in Betatakin could have been exposed to the disease.

Coccidioidomycosis is a fungus disease caused by the coccidia-like fungus, Coccidioides immitis, known to infect man, cattle, sheep, dogs, wild rodents, and other animals. It occurs naturally in the soil and is probably disseminated in dust in the arid southwest. The disease is generally considered to be contracted by inhaling spores carried by the wind. These usually produce lung infections which vary a great deal in severity. Mild cases may be overlooked. Severe cases may show low-grade fever and usually develop nodules resembling tubercles of tuberculosis but can be distinguished by the presence of fungus growths. Occasionally, the organism may spread through the blood and lodge in other places where they develop tumor-like masses in any of the internal organs, around bone, or under the skin. These often break down and ulcerate, leaving a scar when they heal. Betatakin is a dusty region in the path of winds from the low southwestern deserts where spores could originate and be carried by the wind. This is one of the probable diseases to which the aborigines would be exposed.

Leptospirosis caused by organisms of the genus Leptospira of uncertain classification lying between bacteria and protozoans is known to affect both animals and man. The species can at present only be distinguished by their serological properties. An animal host may show more than one serotype without showing symptoms of infection. The organisms are usually spread through the urine of the host. In man, the symptoms may vary from mild fevers to severe infections. Since the disease may be spread by many native animals, exposure of the aborigines is not unlikely.

Spotted fever caused by the rickettsial organism, Rickettsia rickettsii, is endemic in native animals in many parts of the United States. It is reservoired and spread mainly by ticks, the principal source of infection for man. The disease lasts only a few days in rabbits and rodents and may occur in lowland regions where human cases are not prevalent because the lowland ticks do not ordinarily infect man. There is more danger from the highland wood tick which regularly infests man and may carry the organism. The aborigines were undoubtedly exposed to this disease on the plateau or on distant mountains when they went hunting.

Q fever produced by the rickettsial organisms, Coxiella burnetii, has been isolated or found to occur in man and many species of birds, mammals, and their ectoparasites of lice, ticks, and mites from many places in nearly all parts of the world. It was doubtless endemic in the deserts of the west and doubtless occurred in the environment of the aborigines. How it is transferred to man is not well understood.

Endemic Diseases

Rabies produced by a virus is a virulent disease apparently reservoired in bats and possibly in carnivorous animals. It appears sporadically in various parts of the world and is usually transmitted to man by bites from bats, dogs, or other carnivores. It could well have appeared as a sporadic outbreak in the aboriginal environment. There is good reason to believe that other viruses such as the Colorado tick fever and others perhaps still unknown may have occurred in the aboriginal environment.

BIOLOGICAL RESOURCES

In keeping with their urgent needs, these aboriginal people must have gathered biological products for many purposes. A few of the primary purposes served included wood for fuel, buildings, tools, and weapons; edible products for food; fibrous products for strings and ropes; herbs for medicine and dietary supplements; animals for food with secondary uses of furs for clothing and bones for tools; and coloring substances for dyes and body paint. The low degree of specialization and division of labor, and the requirement of doing almost everything for themselves made comprehension of the values and products of their biological resources mandatory in order to time their movements and harvest the natural crops to good advantage.

A review of archeological studies in the Little Colorado River and Glen Canyon basins indicates that at least 50 species of plants, 30 species of birds, and 20 species of mammals played a part in the lives of contemporary aboriginal inhabitants. Modern Indians are known (Yanovsky, 1936) to have used more than 150 plants that occur in this region. It is not known whether those ancient people used the non-seed-bearing plants such as the algae, mosses and ferns but it is known that they used many of the seed-bearing types.

Vegetation

Coniferous Plants

Modern Indians ground horsetails into a flour and made mush. Pines were used for timbers and firewood and seeds of all local species were eaten. Remnants of pine seeds were found in human feces from a Glen Canyon site. Seeds may have been eaten raw, roasted, or made into pine nut butter. Limber pine limbs were sometimes used by Navajos for making bows. Pine gum or resin, especially from pinyon pines has been found and is thought to have been chewed for gum or used for calking purposes, especially in woven basketware or in repairing cracked pottery.

Juniper wood was also used for timber and for firewood where it was available but juniper bark was especially useful. When ruffled into a fine fluff, it was used for tinder and kindling in starting fires. When wrapped into bundles, it could be used for torches or carrying fire short distances. It might also have been used for chinking in buildings or for cushioning purposes. Modern Indians used the cone fruits for food, either fresh or cooked, and for beverages, tonics or medicines by steeping fruits or leaves in hot water. Seeds of ephedra plants may have been roasted, ground into flour and made into bread, while leaves were steeped to make a beverage.

Flowering Plants: Monocots

Cattails were doubtless rare in Betatakin but from the few suitable habitats, young roots, shoots, stem bases, flowers, and seeds could have been utilized for food while the leaves and stems may have served other purposes. They probably utilized many of the 28 species of grasses, sedges and rushes known to be used by modern Indians. Seeds of nearly all species were eaten, fresh, parched, or ground into flour and made into bread, cakes or mush. Some may have been stored. Rootstalks from sedges and rushes may have been eaten raw or made into flour for breadmaking. Even some of the pollen might have been used. Some of the coarse species could well have served as matting.

Wild onions and sego or mariposa lilies may have been eaten for greens or the bulbs may have been dried for winter use, or roasted in hot ashes. The yuccas have fleshy flower stalks and fruits eaten by modern Indians either raw or cooked, and sometimes stored for winter use. These stalks and fruits contain enough saponins to give them a soapy flavor that makes them unpalatable to us but were probably used by the aborigines for food despite the flavor. Root stalks may have been used for soap, ripe seeds ground into flour, and fibrous leaves used for cordage, sandals, basketry and other purposes.

Dicot Plants

Aspens, willows and oaks were probably much used because there were prolific sources of supply near the habitation sites. Timber was used in construction work and wood for fires. Smaller sticks were made into tools and other implements. The inner bark of aspens may have been a palatable food. Oak sticks would have been especially suited for digging sticks, bows, war clubs, and handles. Acorns doubtless made nutritious food that could be stored for winter but might be infested with pests. Flexible willow twigs were suitable for weaving and basketry.

A great variety of plants in the buckwheat and goosefoot groups could furnish greens or seeds for food. Some of both kinds could be eaten raw but others were better cooked. Some of the seeds could be parched or ground into flour and made into bread. Others were suitable for winter storage.

Small tubers of the spring beauty available in early spring could be obtained in the mountains. Many plants of the mustard group could be picked young and cooked for greens. Water cress would be available as uncooked greens. Some of the mustard plants have seeds suitable for food to be eaten raw, stored for winter, or ground into flour.

The roses and related groups have a good deal to offer. Currants, service berries, wild raspberries, rose hips, and choke berries farther down the Tsegi would provide tempting fruits in season. Some could be dried and stored for winter; others might be left and picked in winter. The cliffrose has a shreddy bark that makes good tinder and could be used otherwise like juniper bark. A yellow-brown dye can be obtained from leaves and twigs.

The common legumes of the region containing such products as lupine beans, wild peas, licorice root, prairie clover, and the poisonous locoweed furnished nutritious foods from some species that could be gathered in season in areas where they occur. Locoweed would doubtless be avoided. Roots or rootstalks of prairie clover and licorice might have been chewed, eaten raw, or mixed with other food.

Biological Resources

The geraniums probably supplied some herbs, the flaxes some fibers, and the spurges some medicines or linament. Poison sumac was doubtless avoided but closely related squaw-bushes must have been very useful. The flexible twigs so fine for basketry were strengthened by use of stiffer twigs that helped to hold more rigid form. The sour berries might be eaten fresh, dried or ground into meal. A special drink from the berries and a dye from boiled leaves and twigs are not beyond the realm of probability.

Parts of the boxelder tree were probably used for wood or timber, and the sap may have been used for sugar and seeds for food. Mallows were relatively common and no doubt the tasty green seeds were eaten raw or gathered when ripe. The blazing star furnished both herb and seeds.

Of the good variety of cactuses in the region, some of them certainly must have been utilized. From some, a nutritiously rich wet pulp could be used to quench thirst and could be harvested almost anywhere with a stick or sharp-edged rock. Some of them provided fleshy fruits that could be eaten, dried or stored. Some of the prickly pear sections of stems, when roasted in a fire that would burn off the thorns, could be eaten. The thorns of some species could well have been used like pins or awls.

Buffaloberries may have been eaten and some of the evening primrose and wild parsnip groups may have furnished edible seeds or herbs. The dogbanes and milkweeds would furnish a milky gum and also usable fibers. Many other herbs and seeds might be available at times from such plants as those of the phlox, waterleaf, borage, and mint groups. Variety in flavor might be obtained from the mints.

The nightshade group furnished a variety of products. Wolf-berries were relatively common and might have been eaten fresh or dried and made into soup or mush. Datura leaves and fruits were probably available all through the region but how much they may have been used is not easily assessable. Their poisonous properties probably prevented widespread use but it is known that they were used farther south among modern Indians in producing a stupefying beverage used in mystic ceremonies. Ripened seeds might have been eaten but Navajo Indians recognized their bad effects. Wild tobacco also may have been used for its narcotic properties.

Pentstemon leaves might have been used medicinally by chewing or pounding into a poultice. Monkey flower leaves may have been eaten raw. Other relatives in the Figwort family may have had similar uses. When green, the entire plant of the broomrapes which occur sparingly from canyon bottoms to the mountains, was edible or might be made into a liniment. Green plantain plants may have been eaten. It is suspected that the bedstraws of the Madder family yielded dyes. The pleasant tasting fruits of honeysuckle, elderberry and snowberry were almost certainly utilized either fresh or dried for winter.

The plants with composite flowers had much to offer the prehistoric peoples. Those that provided edible seeds are too numerous to mention. Green leaves and stems such as those of balsamroot, senecio, thistle, and wild dandelions may have been eaten raw, made into salad-like foods or boiled as greens. The roots of balsamroot might be eaten raw or cooked. Beverages might be made from such plants as rabbitbrush and sagebrush. Chewing gum might be made from the roots of Hymenopappus, or the bark of lower stems and roots of rabbitbrush. A dye might be obtained from the latter plant. Dried and pulverized aster plants may have been used medicinally for diarrhea and vomiting. Oil might have been extracted from seeds of such plants as native sunflower or wormwood.

Animals

The three species of toads that probably occur here may have been used for food and the glandular secretions for mixing with other poisons for use on arrow tips. Lizards and snakes were almost certainly used for food and rattlesnake venom may have been mixed with road glandular secretions. In some regions the black widow spider was also included in the poison mixture.

Birds were doubtless used for a variety of purposes. Quails, waterfowl, and perhaps other birds that came to water at the stream in the canyon were probably used for food. Other birds may have been taken for feathers and the bones used for tools. Feathers were used for adornment, for guidance on arrow shafts, and doubtless for other purposes. The chief source of feathers was probably derived from domestic turkeys but the wing feathers of eagles and large hawks must have been eagerly sought for head dress and decoration. Small soft colored feathers may have been used for adornment next to the skin or for ceremonial activities. Bones were probably worked into tools such as awls or needles.

Bones of mammals found in archeological excavations suggest the idea that rabbits formed a major item in their use of animals. The flesh was doubtless used for food, the fur for clothing, and the bones for tools or other secondary purposes. The skins were cut into strips, twisted into long strings and sewed together to make rabbit skin robes.

The bones of rodents represent a wide assortment of many kinds including such forms as ground squirrels, chipmunks, pocket gophers, kangaroo rats, mice, wood rats, and porcupines that may be found at Betatakin. The cumulative evidence indicates the use of these animals as food but the skins may have been made into pouches or other equipment and the bones into tools. It seems probable that the aborigines, like some modern Indians, might have roasted the small rodents whole in hot coals and the entire carcass except the bones eaten. If inadequately cooked, it seems probable that parasites and diseases might have been transmitted this way.

Bones of carnivores, including coyote, gray fox, red fox, badger, spotted skunk and bobcat, found in many excavations suggest the idea that they may have been used by the aborigines but whether they were used for food is a moot question. Probably the fur was the most useful part of these animals.

Among big game animals, deer would certainly have been used extensively as meat for food, hide for buckskin, and bones for tools. It is possible they may have hunted mountain sheep in the rough country and antelope in the desert valleys for similar purposes.

DISCUSSION

It is probable that the Betatakin aborigines were inhabiting a submarginal area of biological productivity that served their needs until harsh handicaps of the environment or social pressures from other peoples made it advisable for them to leave. The lives of these people could be much more intelligently analyzed if the lists of artifacts exhumed from the ruins and environs were available for study. I suggest that the records be gathered and made available at the monument office for future study.

PROPOSED PROGRAM OF INTERPRETATION

It is here recommended that the program of interpretation be focused at the proposed Visitor Center and new campground already planned for construction in the pigmy conifer forest at the head of Betatakin Canyon. Here, at this strategic location, the general features of the region should be presented and key explanations for reaching special attractions made. In addition to services and exhibits inside the Center, the terrace in front is the logical place for orienting the visitor to the features of the colorful panoramic landscape which includes the top of Betatakin Canyon hiding the archeological ruins. The campground behind the Center, located in the heart of the pigmy conifers, will serve to give the visitor an intimate contact with the scrubby trees of this rugged type of vegetation.

Attractions to be reached by trail should be interpreted along the way. These include: (1) a trail leading a short distance to a high point overlook behind the campground to obtain a larger panoramic view than available at the Center, (2) the relatively easy Sandal Trail around the top to Betatakin Overlook where the ruins can be seen in the depths below, and (3) the strenuous Betatakin Trail into the depths of the canyon where the ruins can be visited. Further interpretation may be made at the edge of the present (future overflow) campground overlooking Betatakin from the west side. Additional interpretation may be worthwhile at a Tsegi Canyon Overlook at the end of a road to that point. These features are shown on the map, Fig. 11. Proposals for interpretation at each of these places follow.

A. Visitor Center Terrace

At this terrace in front of the Center, the visitor can be oriented easily to the geographic features of the colorful landscape spreading out northward, Fig. 16A. Here can be seen great stretches of pigmy conifer forests interrupted at intervals by slick bare sandstone or picturesque cliffs where erosional features of Tsegi Canyon are prominently displayed.

Interpretive work at this place should include the following:

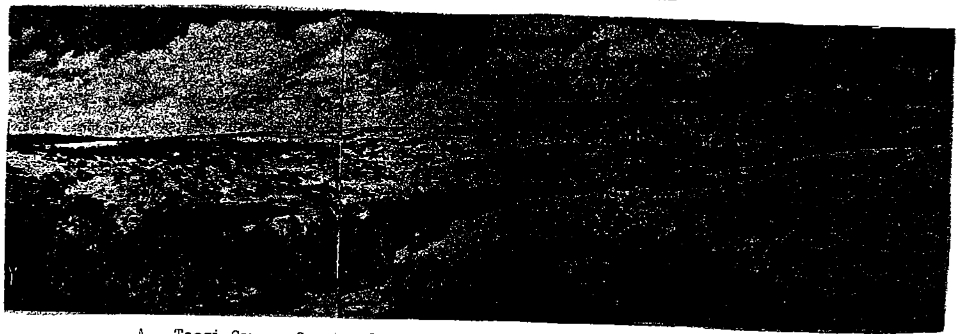
1. An easel-type exhibit showing the panorama to the north and emphasizing:
    a. <u>Pigmy conifers</u> in the landscape
    b. <u>Betatakin Canyon</u> in the foreground
    c. <u>Tsegi Canyon</u> in the distance
    d. <u>Other</u> distant scenes

2. A message repeater giving bird calls of:
    a. <u>Common birds</u> of the pigmy conifers
    b. <u>Wide-spread birds</u> that come to this forest

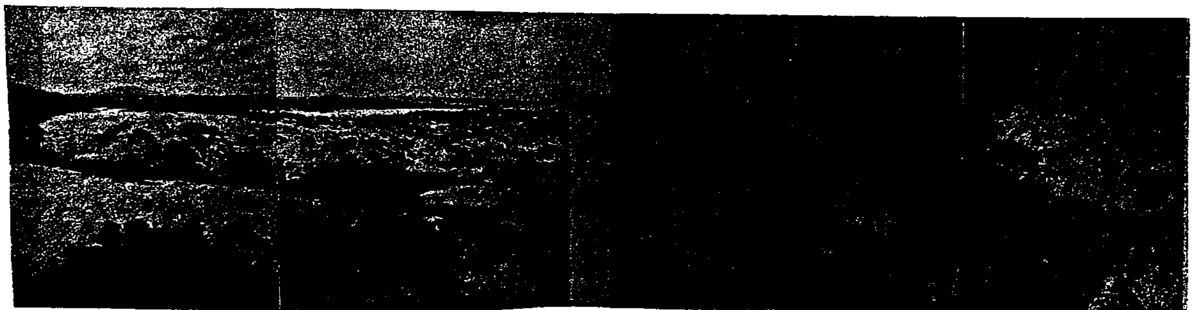
B. High Overlook Trail

This trail should lead west from the campground along a low ridge about 1/4 mile to a high point overlooking the surrounding terrain and commanding a general view of the entire region. Here should be installed an easel type mounting with guide lines pointing to prominent landscape features and supplying regional geographic place names. The trail should be so arranged that people can wander up it at any time and should be provided with suitable signs and information to guide them to the beginning of the trail from strategic places at campground and Center.

VIEWS FROM VISITOR CENTER AND SANDAL TRAIL



A. Tsegi Canyon Country looking north from proposed visitor center across Betatakin Canyon hidden from view.



B. Sandal Trail: View of Navajo Mountain on skyline (left) and Navajo Cove sheep corral (right).

C. Betatakin Overlook: View of Betatakin Ruin Cave (right) and Kiva Cave (left).

D. Betatakin Overlook: Panoramic view of cliffs on northwest side of Betatakin Canyon showing spalling, cliff streaks and cave development.

E. Interesting tree growth along Sandal Trail return loop: a. unusual limb growth, b. juniper growing in solid rock, c. dead juniper roots exposed by erosion, d. pinyon pine crowding out juniper.

Fig. 16. Views: A from Visitor Center, B-E along Sandal Trail. Photos by David J. Jones.

C. Sandal Trail, Fig. 16 B-E.

The primary objective of the Sandal Trail is a sudden deep-canyon view of the aboriginal ruins from the Betatakin Overlook at the end of the trail, Fig. 16 C-D. This view is planned to be supplemented by displays and explanations about these prehistoric people and their environment, both here and at other points. For this purpose, the trail has been designed as a loop to be marked for a one-way circuit, as shown on the map, Fig. 11. The first leg of the trail is planned to keep on high ground past site 1 where a view of Navajo Mountain may be obtained, Fig. 16 B, then descend rapidly to the brink of the canyon at Betatakin Overlook. The return is designed as a gradual climb back to Visitor Center Terrace. Along the way are seven additional sites planned for scenic views and for analysis of the environment.

These sites along the trail are planned as follows:

1. Navajo Mountain View, Fig. 16 B.
   This site at a high point on the Sandal Trail overlooking the head of Betatakin Canyon provides a distant view of Navajo Mountain rising majestically over the intervening plateaus. This mountain, which can also be seen from High Overlook, forms an integral part of the background necessary along the Sandal Trail for explaining the "inverted" mountain vegetation in the bottom of Betatakin Canyon. Provide an easel-type exhibit:

   a. Identifying Navajo Mountain as an unexploded volcano (laccolith). Associate it with LaSal, Abajo and Henry mountains and contrast it with volcanic San Francisco peaks.

   b. Explaining vegetation belt sequence on the mountain and the presence of similar vegetation in Betatakin Canyon due to "canyon effect".

   c. Fix monoculars on Navajo Mountain vegetation and on isolated pine stands on closer horizon.

2. Betatakin Overlook, Fig. 16 C-D.
   This overlook on the brink of the deep canyon gives a remarkable view of the aboriginal homes in a large cave across the canyon, Fig. 12. A protecting wall and a shelter here should provide the visitor with a feeling of safety and comfort. Exhibits at this place should include the following:

   a. The chief exhibit here should stress the homes of the aboriginal people and the environment in which they lived. Explain the building sequence and use photos to show architectural features. Illustrate the mode of life by drawings and replica of a room.

   b. Geology of Betatakin Canyon as provided by geologists; general considerations of the Paleo-ecological interpretation of environments, leaving more detailed aspects for treatment at the drop-off on Betatakin Ruin trail.

Sandal Trail

2. Betatakin Overlook, continued.

   c. Easel exhibit at the guardrail wall explaining the developmental processes and theoretical sequence of alcoves and caves visible on the cliffs across the canyon, Fig. 16 D.

   d. Tie the development of alcoves and caves to the seeps, trickles, and springs of water that overflow through the porous sandstones from the subterranean water storage in Klethla Valley released through these aquifers.

   e. Explain the development of springs in the canyon as a result of cutting aquafers by erosion and subsequent enlargement of the water pathways by solution of the binding materials that hold the sand grains together.

3. Down-canyon view, Fig. 13.

   On the return leg of the loop trail, not far from Betatakin Overlook is a beside-trail stop point giving a better scenic view of the canyon. A marker should indicate it as a scenic view unless further investigation warrants transferring here the geological data (2-b) planned for the Overlook.

4. Tree growth, Fig. 16 E.

   Beyond the down-canyon view on the return loop of the trail are several trees that show unusual growth patterns. At a suitable place, provide an easel-type exhibit to indicate and explain these unusual growth characteristics:

   a. A leaning tree, Fig. 20 H.
   b. Tree with unusual terminal leading shoot, Fig. 16 E-a, growing in solid rock.
   c. A juniper tree with roots exposed by erosion, Fig. 16 E-c.
   d. Report study of age of trees from core borings.

5. Up-canyon view, Fig. 18 A.

   Along the brink of the canyon is another beside-trail stop point giving an excellent view of the head of the canyon below the drop-off and showing an abrupt change of vegetation above and below. Here is a good opportunity to provide an easel exhibit showing:

   a. The ecological change bringing "inverted" mountain vegetation into the bottom.
   b. Location of the suspended trail around the drop-off on Betatakin Ruin trail.

6. Kiva Cave View, Fig. 18 D.

   Before leaving the brink of the canyon for the return ascent through the pigmy forest, is a final beside-trail scenic view into the canyon revealing the Kiva Cave in an esthetic setting. A trail-side marker should indicate the site.

Sandal Trail.

7. Juniper-pinyon Pigmy Forest, Fig. 17.

On the return loop part way up the slope, the trail passes through a good stand of junipers and pinyon pines that illustrate this type of forest. Since much of the soil cover between the trees being held in place by lichens and mosses, Fig. 18 B,C, is very fragile, some sort of protection such as a wire alongside the trail might be used to encourage people not to trample these delicate structures outside of the trail. It is proposed to provide a wayside shelter and exhibits here to depict:

a. The dominant plants of this forest and some of their sub-dominant associates, Fig. 17.
b. Significant environmental factors associated with this forest.
c. Extent and geographic distribution of this forest type.
d. A pinyon pine crowding out juniper, Fig. 16 E-d.
e. Products of the forest for human and animal use: food, fuel, nesting material, shelter and others.
f. Lichen - moss - soil relationships between trees, Fig. 18 B,C.
g. Relationship of root and foliage volumes.
h. Effect of litter and shade on soil.
i. Associated animals, vertebrate and invertebrate.
j. Food-energy transfer cycle.

8. Slick Rock Lichen-Moss Cover, Fig. 18 E-L.

On this return loop between the pigmy forest exhibits and the Visitor Center, the trail passes close to an area of slick rock showing various stages of lichen-moss-vascular plant development on the rock surface. Since this is also a sensitive surface easily disturbed or ruined by trampling, protective measures should also be developed here for special plots. Easel exhibits and related plant labels should be provided to depict:

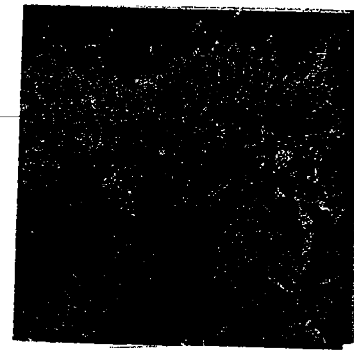
a. Primary covering of lichens, usually one type following another until thin covering of soil is developed, Fig. 18 E, F.
b. Moss entering lichen cover, small dark dots in Fig. 18 F,G,H, and developing into large patches of inch-deep soil, Fig. 18 G,H,I.
c. Entry and development of seed plants in soil held in place by mosses, Fig. 16 J, K.
d. Effect of erosion removing accumulated soil, Fig. 18 L; results of erosion like this when disturbed making the San Juan River one of the muddiest rivers known, much of it from livestock trampling.

D. Betatakin Ruin Trail, Figs. 19, 20, 21.

The primary objective of this trail is a visit to the ruins left in the Betatakin Cave by the aboriginal inhabitants of the 12th and 13th centuries. Secondary objectives include further analysis of their environment at selected sites along the way. For these, I suggest a single trail from the Visitor Center to the bottom below the drop-off and a loop trail in the bottom. For location to be determined by survey, I suggest that consideration be given to locating the trail as follows: swing the single trail from the Visitor Center wide to the northwest on a suitable grade nearly to the slick rock, then switch

A. A pinyon pine (right) crowding out an older juniper (left).

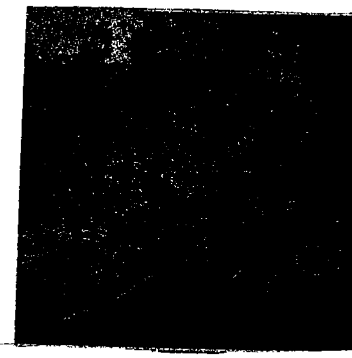
B. Litter under pinyon pine provides moisture-holding humus.



C. Big sagebrush shares the dominant position with junipers and pinyon pines.

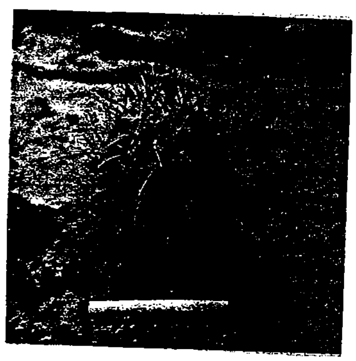
D. General view of mountain mahogany among the junipers and pinyon pines.

E. Close-up view of mountain mahogany.



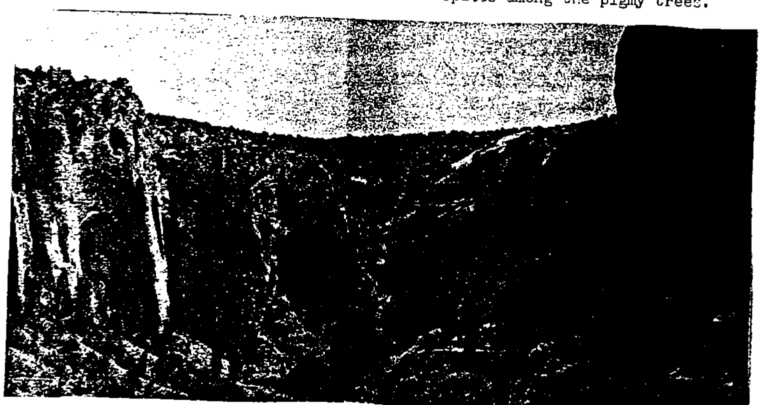
F. The Fendler bush among the pigmy conifers.

G. Silver buffalo berry and two species of cactus in pigmy forest.



H. Beehive cactus grows in open spaces among the pigmy trees.

I. Hedgehog cactus also grows in open spaces.



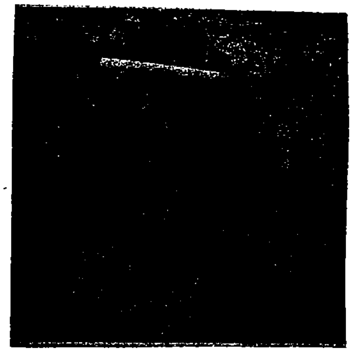
J. View up Betatakin Canyon showing pigmy conifers, canyon above drop-off, firs (left, foot of cliffs), and aspen (center foreground).

L. Grizzly bear cactus also shown in G (right foreground)

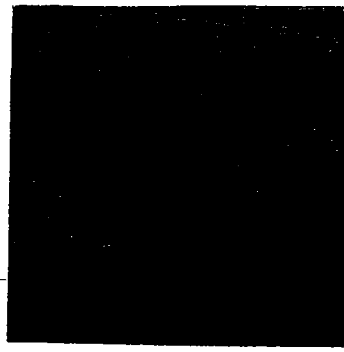
Fig. 17. Some of the common plants of the pigmy conifers. Photos by David J. Jones, except J by American Exploration Society. (Courtesy of Museum of Northern Arizona).

A. Up-canyon view from canyon rim.

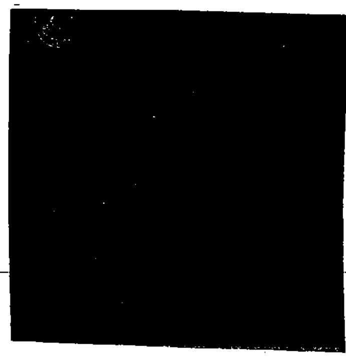
B. Sculptures of the soil held in place by moss.



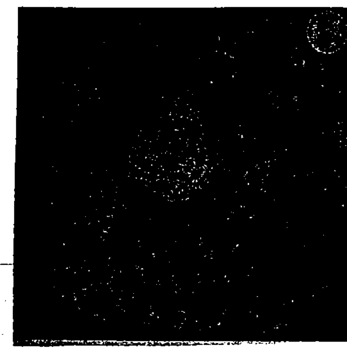
C. Another form of soil sculpture by moss.



D. A view of Kiva Cave from canyon rim.

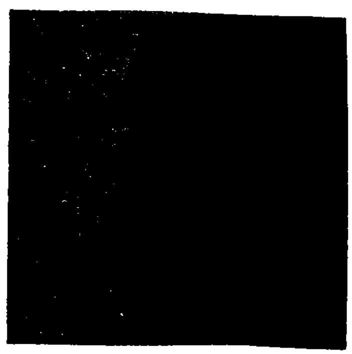


E. Lichens coating bare rock on trail approaching Visitor Center.



F. Moss (small dark dots) penetrating lichen cover on bare rock.

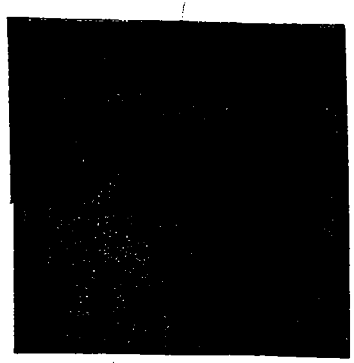
G. Moss spreading among lichens.



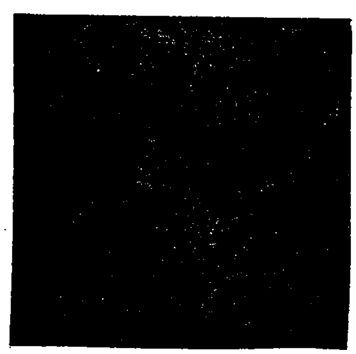
H. Well-developed round patch of moss.

I. Irregular shaped moss patch.

J. Seed plants established with roots in rock.



K. Sandy soil accumulating around seed plants rooted in rock.



L. Pinyon pine tree with roots in rock uncovered by erosion.

Fig. 18. Views along return loop of Sandal Trail.
Photos by David J. Jones.

back down the head of the canyon to the ledge at the Three Firs, pass around this ledge to the left, switch back right to the base of the Three Firs and go on down the canyon to the drop-off. Put the Twisted Fir Nook on a spur. At the drop-off, run the hanging trail on suitable grade on the right to the fir trees in nooks at the base of cliffs high on the hillside, continue on suitable grade down canyon to a point where a switchback can be made left to reach bottom of canyon. Put Saucer Cave on a spur. From bottom, run trail down canyon through "inverted mountain" vegetation, then upslope to ruins in Betatakin Cave. From this cave, run trail on suitable grade around sidehill up canyon overlooking the mountain vegetation to end of loop in canyon bottom. Put Kiva in second cave on spur. The thousand foot climb back to the top will require several rest stops.

The sites along this trail are planned as follows:

1. <u>Cross-bedding in Navajo Sandstone</u>.
Provide easel exhibit explaining significance of cross-bedding in the interpretation of origin of Navajo sandstone using a suitable photo and diagram of a dune in the Great Sand Dunes National Monument for comparison.

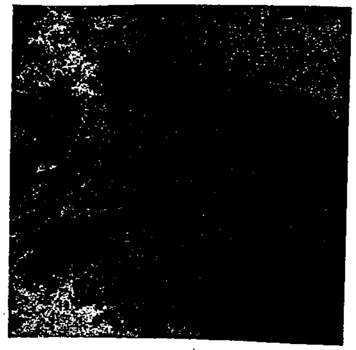
2. <u>Three Firs Rest Stop</u>, Fig. 19 A,B,C,D.
Easel exhibit to identify Douglas fir trees and show the age of the three examples here from tree ring borings. It is suggested that the trail pass on the left side of the canyon around the ledge above the trees to a point where a switchback can be made to bring it back below the ledge and cross the wash to the rest stop in the shade of the three trees. This is the last full-shade rest stop before reaching the top. If the trail follows a different route, this site should be abandoned.

3. <u>Twisted Fir Waterfall Nook</u>, Fig. 19 E-L.
This site is approximately on the same level as the Three Firs and should be on a spur on side loop. It is a good location for more detailed analysis of contrasts in the desert environment where those who are specially interested in such studies can find suitable explanations. It is located at a point where temporary streams from a short drainage basin pour over a north-facing cliff. In addition, seepage from the lower part of the cliff face provides water for a small "hanging garden" (miniature like those of Zion Canyon), Fig. 19 E, G, H.

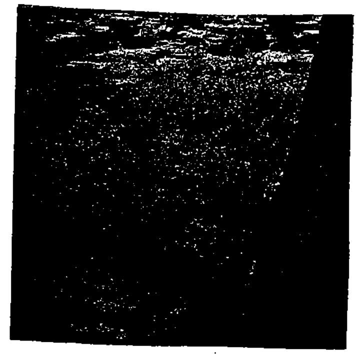
This shady nook in a pigmy conifer forest shows conspicuous contrasts in vegetation provided by this physiographic feature. Because of shade and additional moisture, plants otherwise excluded can grow here. An easel exhibit to explain these relationships is suggested. Illustrate this by showing the hanging garden, a type of vegetation particularly well illustrated at Weeping Rock and the Narrows in Zion National Park. Point to Douglas fir and pinyon pine growing within 10 feet of each other whereas they are normally separated by as much as 1000 feet of elevation, Fig. 19 J.

Of special interest is the twisted fir, Fig. 19 F, a partly dead tree with living tissue spiralling around the dead trunk and having many of the dead roots exposed by erosion. Date the tree by core borings and

A. The Three Firs looking from above.

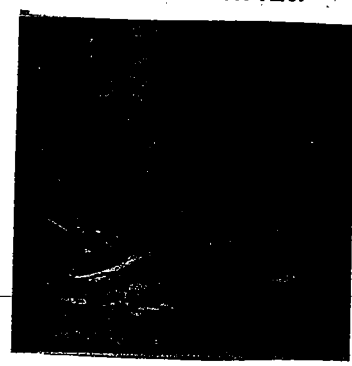


B. Looking below ledge at foot of Three Firs.



C. Looking up-canyon at Three Firs rest stop.

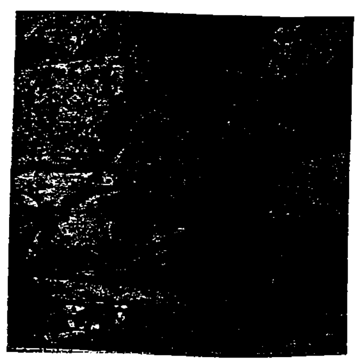
D. Looking down-canyon from Three Firs rest stop.



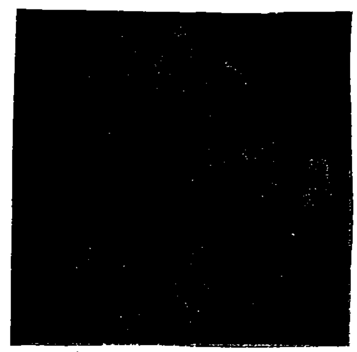
E. Nook beside twisted fir.

F. Twisted fir showing twisted growth, exposed roots and woodpecker hole.

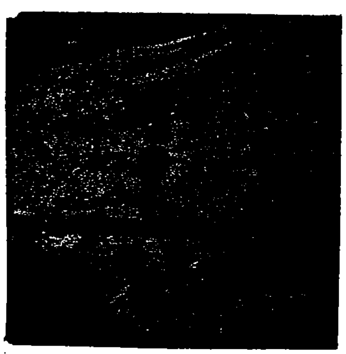
G. Detail of cliff face at nook showing alumroot and grass.



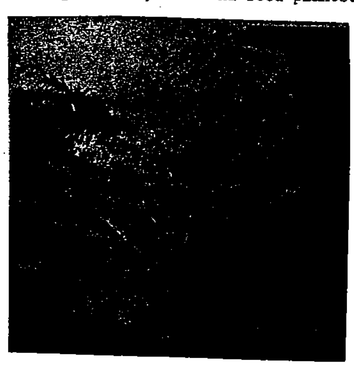
H. View of cliff face at nook, showing lichens, moss and seed plants.



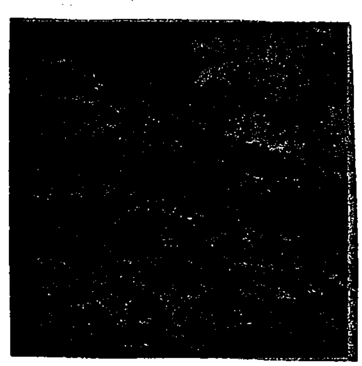
I. Detail of lichen growth on exposed root of twisted fir.



J. View near nook showing fir (left) and pinyon pine (right) growing near each other.



K. Details of young fir showing details of annual twig growth.



L. View of Navajo Cove sheep corral from nook.

Fig. 19. Views along Betatakin Trail above Drop-Off. Photos by David J. Jones.

Betatakin Ruin Trail

3. Twisted Fir Waterfall Nook, continued
calculate the amount of erosion during its lifetime. Explain role of lichens and moss in breaking down dead wood of these exposed roots, Fig. 19 I. Point out grass invading the moss and the grass and wet rock plant crowding out moss in the hanging garden, Fig. 19 G, H. Provide a diagram to show how to read the age of the Douglas fir, Fig. 19 K.

4. Navajo Sheep Corral, Fig. 19 L.
From a suitable point on the trail below twisted fir, provide a trailside label pointing out a former Navajo sheep corral in an alcove just across the canyon (northwest). Explain that this corral was presumably used by the Navajos about 1860 to hide out from the U. S. Army. This alcove contained a small prehistoric ruin that was almost ruined by use as a sheep corral. Similar "unintentional vandalism" has ruined many other pre-historic sites.

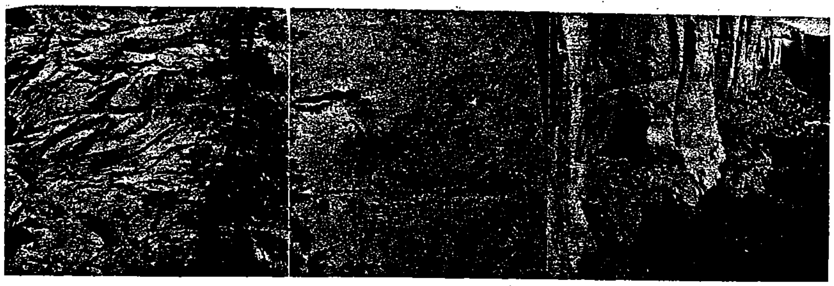
5. Drop-off, Fig. 20.
This drop-off site at the top of a cliff, Fig. 20 C, provides a magnificent view of the canyon, Figs. 13 and 20 D, and is the logical place for full development of the idea of "canyon effect". A wayside shelter at the site at the top of the drop-off can be used to explain:

a. The geological formations visible in Figs. 6, 12, 13, 17 J, and 20 D.
b. The erosion process in the canyon, recent erosion terraces below, the cliff making process and alcove formation as revealed on cliff faces; supplement data given at Betatakin Overlook (C-2).
c. The effect of shading by the cliffs on the vegetation in the deep canyon.
d. Detailed ecology of dry rock plant, Fig. 20 I, J.
e. Details of cross-bedding in sandstone in adjacent rocks, Fig. 20 E,F.
f. Story of ant lion craters under shelter of above rocks, Fig. 20 G.

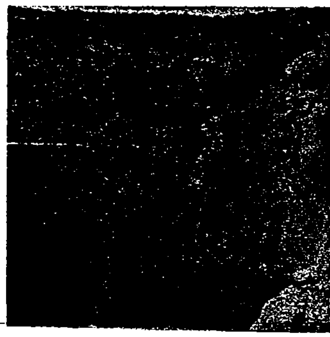
6. Suspended Trail
I suggest, if engineering is feasible, that this suspended trail follow on suitable grade around the cliff to the right and land in the fir nooks there at the foot of the cliff in left foreground of Fig. 20 B. Suitable explanations about the suspension should be placed at each end. At the lower end, benches for a rest stop should be provided for rest in the shade of the trees.

7. Inverted Mountain Forest
At the first switchback turn below the preceding rest stop, a trailside marker should announce that the visitor is about to enter the inverted mountain forest, normally found on high mountain tops such as Navajo Mountain but growing here because of the canyon effect. A message repeater giving calls of birds likely to be found in this canyon would be an added attraction. It could be used to alert visitors going down and to check coming back.

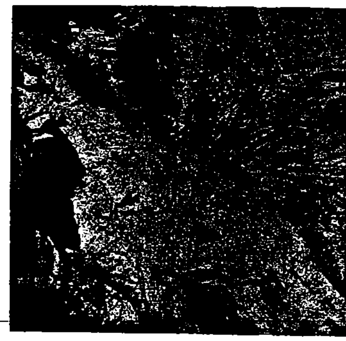
8. Saucer Cave
At the end of a spur trail, this interesting cave could serve as a rest stop with bench, a shelter in case of rain, and a study in cave formation. A marker should explain the striking cross bedding as originally formed in a dune and its influence in development of this cave.



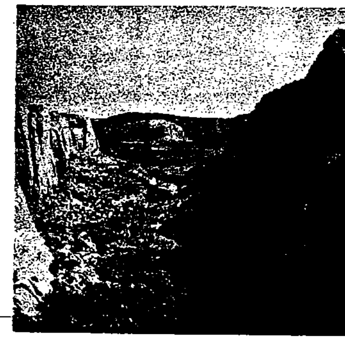
A. Panoramic view of north side cliff face from drop-off.



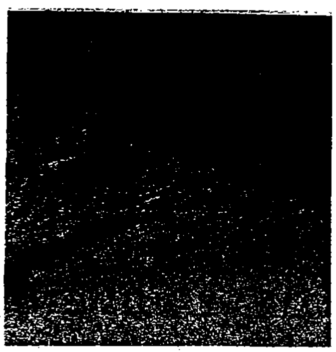
Betatakin Canyon above drop-off.



C. Proposed site for wayside shelter above drop-off cliff.



D. Down-canyon view from top of drop-off cliff.



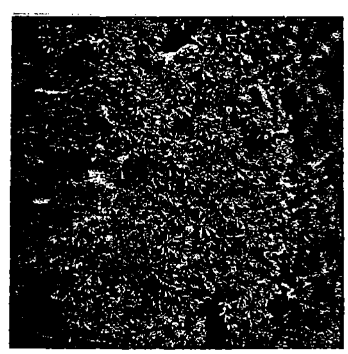
E. Cross bedding in rock near drop-off and ant-lion pits in soft sand.

F. Close-up of cross bedding.

G. An ant-lion pit shown in E.

H. A leaning tree in solid rock on south rim at up-canyon view.

I. Dry rock plant <u>Petrophytum caespitosum</u> on ledge near drop-off.



J. Close-up view of dry rock plant.

Fig. 20. Views around the site of proposed wayside shelter at drop-off above cliff in canyon head. Photos by David J. Jones.

Betatakin Ruin Trail

9. Horsetail-Meadow Rue Vegetation, Fig. 21 B, C.
If the final location of the trail traverses this small area of meadow-like vegetation in the bottom of the canyon, a trailside marker should point out the primitive plant characteristics of the horsetail, here growing in close association with meadow rue under conditions of more moisture and high humidity. Also call attention to increased incidence of moss and rock plants, Fig. 21 I, L.

10. Cliff Streaks, Fig. 21 J.
At a suitable place on the loop trail where the cliff streaks are visible, provide a marker attributing the streaks to deposit of mineral dissolved out of rocks. Explain difference from ordinary desert varnish as accelerated deposition where water trickles down face and evaporates.

11. Oak Grove, Fig. 21 A.
At suitable place along first arm of loop trail, use a marker to explain basic ecology of oak grove, suitable moisture-temperature relations, its habit of clone spreading, and its ability to shade ground, provide leaf litter and hold more of the moisture from precipitation. Also, its acorn crop and shade doubtless relished by the aborigines.

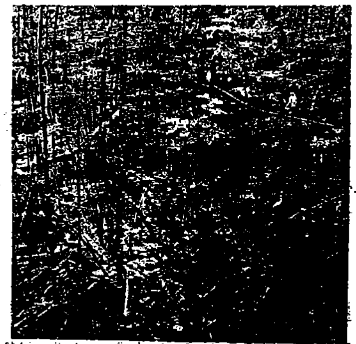
12. Aspen Grove, Fig. 21 D-H.
At appropriate place on the first leg of the loop trail, provide marker and trail labels explaining:

- a. Contrasting ecological role in canyon bottom "inverted" forest and on high mountain where it paves way for invasion of large conifers.
- b. The work of bark beetles, Fig. 21 E-H, and woodboring beetles, center Fig. 21 G.
- c. Spreading of aspen by root coppice growth, Fig. 21 D.
- d. Use whittling post and not aspens for initial carving.

13. Gathering plants.
At a selected site along the trail, provide a marker explaining that the aboriginal peoples gathered products from many native plants for food, medicinal purposes, fibers, structural materials, bows, arrows, and many other purposes. At suitable places along the trail, place labels naming the plant and explaining the uses of the plant by the aborigines and other information of significance about the ecology of the plant. Those labeled should include all major plants not otherwise treated.

14. Birch.
At a suitable place along the lower part of the trail, provide a marker identifying the birch as a streamside plant with roots immersed in soil water derived from the stream. Call attention to other streamside plants such as the dogwood.

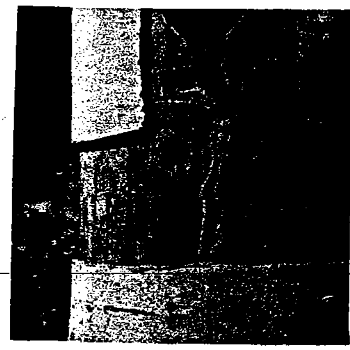
A. The dense oak grove is above the aspen of the bottom.



B. Dense horsetails and meadow rue along stream in bottom of canyon.

C. Close-up view of horsetail.

D. Some of the aspen trees have fallen.



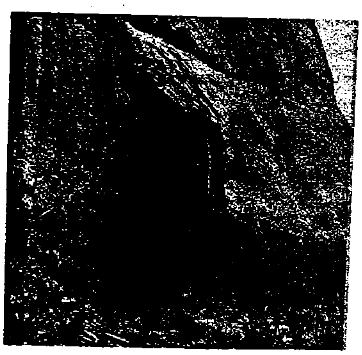
E. An old live aspen riddled with bark beetle borings.

F. Beetle path on standing dead tree; made before bark fell.

G. Work of bark beetles and wood borers (center pile) in fallen aspen

H. Beetle paths in fallen aspen.

I. General view of a hanging garden on cliff face near Saucer Cave.



J. Streaks on face of north side cliff made by seeping water.

K. Leaf-roller caterpillar work on dogwood near water pump.

L. Detail of hanging garden shown above at I.

Fig. 21. Views of the inverted forest in canyon bottom.
Photos by David J. Jones.

Betatakin Ruin Trail

15. Betatakin Ruins, Fig. 16 C, D, right center.
On trail at entrance to ruins, provide sign identifying the site and general instructions about conduct necessary for visitor safety and protection of ruins. To supplement the naturalist guide talks, a series of suitable labels and explanations provided by anthropologists should be available at appropriate places throughout the area covered by the ancient structures. Arrows may be useful in guiding the visitor through the area and to the exit trail.

16. Kiva Site, Fig. 16 C, D, left center.
At the end of a spur trail leading to the second large cave, place a marker, giving drawing of reconstructed kiva and explaining its use. Give special instructions for behavior, if needed. Use arrows to indicate routes of travel.

17. Animal Life.
At a suitable shady spot on the return leg of the loop trail, provide a rest stop with seats and a marker explaining the kinds of animals occurring in this deep canyon as a medley of those normally found in the desert and pigmy conifers and those usually found in mountains brought in here by the "inverted" mountain ecology (see text under Materials).
These may include:

1. Invertebrates
   a. At least nine species of land snails in litter.
   b. Pillbugs and other crustaceans (to be determined).
   c. Millipeds and centipeds (if substantiated).
   d. Numerous insects (including leaf-rollers of the dogwood),Fig. 21 K.
   e. Unknown numbers of arachnids.

2. Vertebrates
   f. Probably one salamander and three toads.
   g. Possibly seven lizards and five snakes.
   h. Possibly six bats, three rabbits, 15 to 20 rodents, six carnivores and one deer (now extinct, untenable in Navajo sheep economy).
   i. At least 20 species of birds.

E. Tsegi Canyon Overlook

At the end of the road at Tsegi Point, a terminal for auto traffic and beginning of trail to Keet Seel where an immense view of the Tsegi Canyon heads is available, an easel exhibit should be provided to show the location of special features of the landscape.

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